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PLATE I. *page 44.*

Fig. 1.

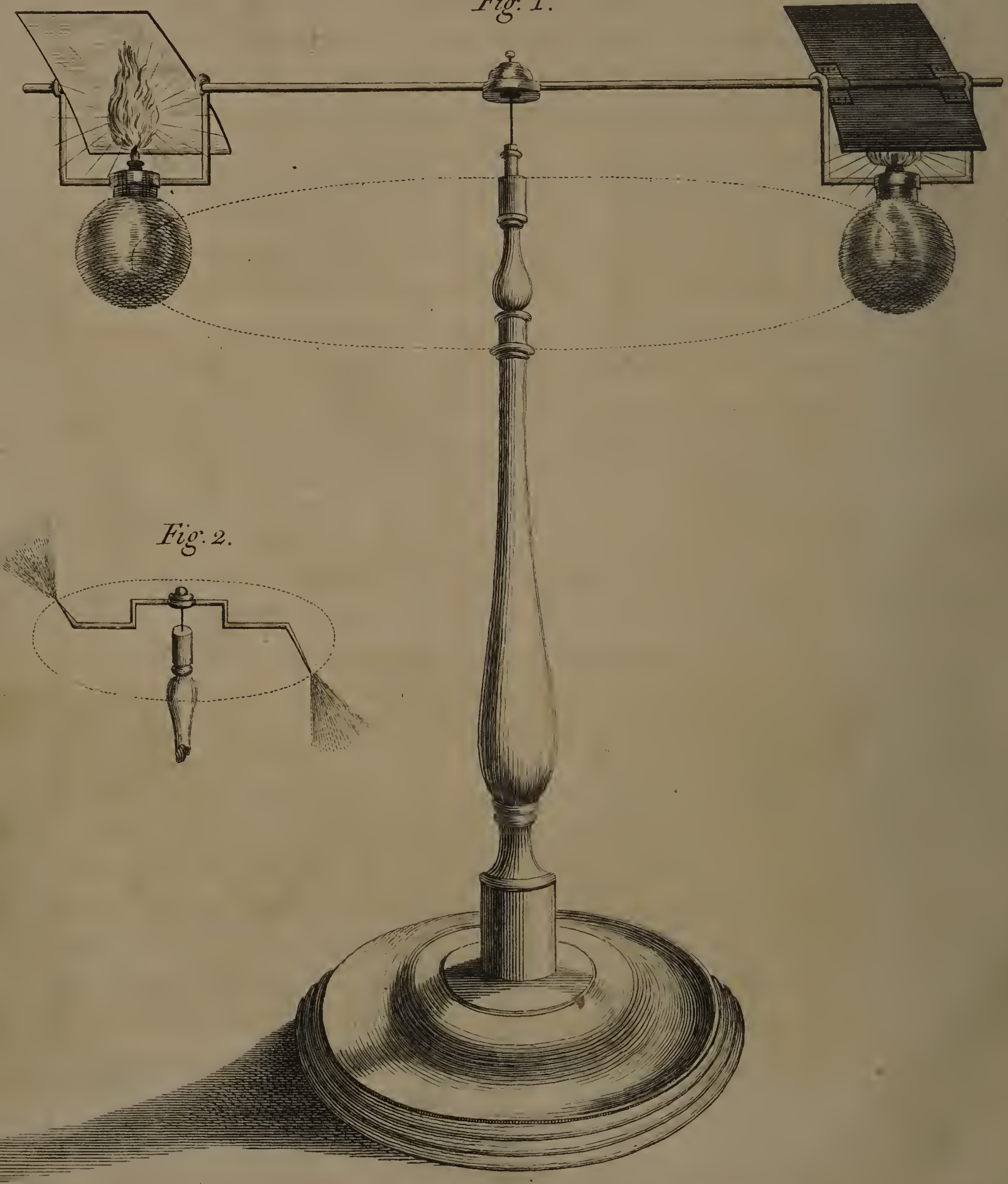

Fig. 2.

W. Iones del. *I. Mynde Sc.*

AN

ESSAY

ON THE

FIRST PRINCIPLES

OF

NATURAL PHILOSOPHY:

WHEREIN

The Uſe of NATURAL MEANS, or SECOND CAUSES,
in the OEconomy of the material World, is demonſtrated from REASON, EXPERIMENTS of various
Kinds, and the TESTIMONY OF ANTIQUITY.

IN FOUR BOOKS

Illuſtrated with Copper-Plates.

Και σωφρων ημαρτε, και αφρονι πολλακι δοξα
Απτετο. Theog.
Multa renaſcentur quæ jam cecidere. Hor.

By the REVEREND WILLIAM JONES,
Late of *Univerſity College* in *Oxford*; and Author of
The Catholic Doctrine of the Trinity.

OXFORD,

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AN ESSAY, &c.

BOOK I.

On *the* Mechaniſm *of Nature; or the uſe of* natural means *in the producing of phyſical Effects.*

CHAP. I.

The Introduction. Some occaſional reflections on the prejudices of philoſophers. Apology for the author, with an account of his deſign. Two different ſyſtems of philoſophy briefly explained.

GOD having created the world for the benefit of all mankind, every man has a natural liberty of enquiring into the ſtructure of it, and examining the various motions that appear in it, with their ſeveral dependences, circumſtances and cauſes: a ſtudy highly commendable, if conſidered only as an inexhauſtible fund of innocent amuſement, but worthy of a better name, when applied to its proper uſe: for if it be not our own fault, we may *out of the good things that are ſeen know him that is*; and *by conſidering the works*, be led to *acknowlege* the power, goodneſs, and unſpeakable wiſdom of the *workmaſter*.

IN this inquiry, though a man may reap many advantages by ſeeing with the eyes of others, who could ſee farther than himſelf, and is greatly to be blamed if he does not make uſe of the opportunity; there is certainly no law that obliges him to keep his eyes ſhut, where his own ſafety and ſatiſfaction require him to open them. The conſtitution of the world, together with the powers, cauſes or principles upon which the operations of nature depend, being matters of fact, and not points of ſpeculation, it is *evidence* alone that can lead us to any rational determination.

MY deſign at preſent therefore is to collect as much of this evidence, as the caſe can reaſonably be thought to require, and lay it before the publick, without any regard to the ſyſtematical reaſonings, or reputed authority, of this or that philoſopher in particular. In the proſecution of this deſign, I ſhall endeavour to expreſs my mind with freedom and impartiality, as a man ought in conſcience to do, who has no private ends to ſerve, and does not deſire, that the value of what he has written ſhould be determined by the favour of his friends, but rather that his enemies, if he has any, would rigorouſly compare it with their own obſervation and experience.

IF we are not free from thoſe vulgar prejudices — that it is a great misfortune to be ſingular — that the multitude (who have been always changing) muſt neceſſarily be in the right — and that the *laſt* writer, who has obtained a name in any ſubject, is to be followed implicitly in every thing he has propounded; we ſhall be afraid to *enquire*, and to endeavour to advance the progreſs of true and uſeful knowlege, as we all profeſs to do, and all ought to do; but ſhall rather fall upon the fruitleſs labour of accommodating every new diſcovery to the principles we have already received, looking at the ſame time with a ſuſpicious eye on every writer, who with regard to any particular article would turn us out of the beaten track. An ancient maxim of the once-celebrated *Thomas Aquinas* — *Cave ab illo qui unicum librum legit* — deſerves to be conſidered by all thoſe, who dare not venture abroad in queſt of truth, but behind the back of their tutor: in which ſituation, they may poſſibly ſee ſo much of *him*, as to be able to ſee nothing elſe.

It will readily be granted, I ſuppoſe, that ſuch a practice as this is very childiſh and abſurd, provided the obſervation be applied only to the prejudices which once reigned in favour of *Ariſtotle*, *Des-cartes*, or the *Chymiſts*: yet it ſo happens, that if an author comes home to his own times, and ventures to look into any of the pretenſions of the preſent age, he is in danger of being aſſaulted by all that meet with him; and generally with the greateſt vehemence by thoſe who are the moſt ſuperficial in their knowlege.

This conſideration, I frankly confeſs, hath ſometimes had ſo much weight, and appeared ſo formidable to me, that I have been almoſt tempted to throw my pen into the fire, rather than employ it againſt any current opinion. A ſincere love however of the ſcience of nature, and a confirmed perſuaſion both of its uſefulneſs and its importance, ought to prevail againſt theſe difficulties; and they have prevailed with me, to try, in the firſt place, if I can diſpel ſome of that learned darkneſs with which the ſubject has been overſpread, and open the way to a better underſtanding of it.

And here I cannot but reckon it a great advantage to truth, though it is none at all to myſelf, that in peruſing the following ſheets, the reader is in no danger of being dazzled or miſled by the influence of a name ſo inconſiderable as that of the author; who has no popular prejudices to appeal to, and cannot expect to be heard upon any conſiderations, but the importance of the matter, the clearneſs of the facts, and the ſtrength of the arguments, he has to propoſe.

Why this attempt ſhould give offence to any perſon, he cannot well imagine. For if we divide the world of philoſophers into two parties, ſome of whom are influenced by an undiſſembled zeal for the Chriſtian faith, while others are not aſhamed to declare that they have no religion at all; the former, I preſume, can have no good objection to any phyſical diſquiſition, which is conducted with ſubmiſſion and modeſty; it being impoſſible that true religion and true philoſophy ſhould be at variance; becauſe He who created all thoſe works, which are the proper objects of natural philoſophy, was alſo the author of divine revelation; and God is not divided againſt himſelf. And unleſs it were in my power to point out ſome particulars, in which this diſquiſition may prove to be of ſervice to religion, I ſhould be able to give but a poor account of thoſe many hours, which I have been obliged to borrow from that profeſſion and ſtudy, to which the providence of God hath more immediately called me. As to the latter, they I think who are ſo forward to tell us, they have rejected all human authority, and can *think freely* in matters of religion, will not be very conſiſtent with themſelves, if they are angry with me for thinking as freely in matters of philoſophy.

This ought to be remembered likewiſe for the ſatiſfaction of all parties, that if the method of explaining natural effects, now in vogue amongſt us, be eſtabliſhed on ſufficient proof, or rather, as it is commonly reported, on undeniable demonſtration; all that I ſhall occaſionally offer againſt it, though it may puzzle ſome ſuperficial readers unacquainted with the ſubject, will not weaken it in the opinion of any man of true learning and judgment. If it be not eſtabliſhed on ſufficient proof, what harm will there be in diſbelieving it? we ſhall then be at liberty to turn our thoughts another way, and may be looking out with ſome better proſpect of ſucceſs. And as it appears, to me at leaſt, that no *Phyſical Effect* is really explained or underſtood, unleſs it is deduced from a *Phyſical Cauſe*, the exiſtence and operation of which can be experimentally demonſtrated; I ſhall humbly endeavour to ſhew, that the modern philoſophy, although it has carried natural knowlege to a great height in ſome reſpects, can furniſh no ſound arguments or real objections againſt the *mechaniſm* of the natural world; and that in every thing it has advanced againſt this mechaniſm, it doth itſelf proceed upon ſuch principles, as are arbitrary, and unſupported by any evidence that is truly philoſophical or phyſical. Theſe I know are very bold aſſertions; but if the reader will only prevail with himſelf to bear with me for a while, and have a little patience, he may perhaps find ſome reaſons, more conſiderable than he is aware of, for being of the ſame opinion.

EVERY perſon, who makes uſe of his ſenſes, muſt needs be convinced, that the matter comprehended within this viſible world is full of motion; and the learned have very greatly doubted, by what means, and after what manner, this motion is ſupported and preſerved. Some of them, according to their own accounts, begin with the two principles of *matter* and a *void ſpace*. To their matter they give this capital *Law*, that if once moved, it ſhall continue in motion, becauſe it has no power to *ſtop itſelf*. Thus they elude the neceſſity of providing any *phyſical* cauſe for the conſervation of motion, and ſave themſelves all that trouble, which they might otherwiſe have in ſearching after it. Then, from the principle of a *vacuum*, or ſpace void of all ſenſible matter, they propoſe the two following advantages; that a body will have *room* wherein to move, and that being once ſet a going, there will be nothing in the way to obſtruct or diminiſh the quantity of its motion.

In this manner they account for the continuance of that motion which is rectilinear: but then for the producing of other motion in curves and compounded directions, with which nature is obſerved very much to abound, they ſuppoſe an emiſſion of immaterial virtues or forces, propagated through their *vacuum* from one parcel of matter to another far diſtant from it. Theſe virtues are of two ſorts: by the one of them, one body is ſo affected by another, as to be *drawn nearer* to it; by the other, it is cauſed to recede from it: and neceſſity requires upon ſome occaſions, that the ſame parcel of matter be allowed, and that in all its component parts, to have both theſe powers, though contrary to, and deſtructive of one another. The names by which they have been diſtinguiſhed in different ages are εχϑρα and φιλια, *love* and *hatred*, *ſympathy* and *antipathy*; and now they paſs current under the faſhionable terms of *attraction* and *repulſion*. But I preſume if we were to call them *a pulling without any hold*, and *a puſhing without touching*, we ſhould deſcribe all the ſenſe they have, as well as diſtinguiſh one from the other. How or when theſe qualities came into the world, and *what* they really are, this ſort of philoſophy thinks itſelf not concerned to declare; but only to affirm that there *are* ſuch; and if preſſed either with difficulties or abſurdities, has this to offer in its defence, that the world is over-ruled by a ſupreme intelligence, which can act in *any manner*, and which appears from ſome obſervations to act in *this* manner.

THESE are ſome of the out-lines of that coſmographical ſyſtem, which was taken up, and cultivated with all the geometrical ſkill of the great *Sir Iſaac Newton*; who, as an honourable author has truly obſerved of him, "was made "by nature and inclination for mathematical ſtudies." * Moſt of our celebrated mathematicians, who are led by a natural bent to a like method of reaſoning, are confident, that he has transfuſed into phyſical ſubjects the certainty of geometrical demonſtration. Hence they tell us, he *has ſecured his philoſophy from the hazard of being diſproved*; and have accordingly beſpoken all the *diſcoveries* that ſhall happen to ariſe in *future ages*, which, it ſeems, are to *confirm and enlarge his doctrines, but can never refute them.* † Whether the caſe does in all points come up to their deſcription of it, we ſhall be better able to judge, I hope, from the contents of the following ſheets.

OTHER philoſophers there are, who believe the frame of nature to be a perfect and well-ordered machine: in other words, that the viſible ſyſtem of the world, created, diſpoſed, and ſet into motion by the finger of God, acts as a machine does; a connection and communication being preſerved between all the diſtant parts of it; for if you interrupt the contact of a machine, you deſtroy its motion in all thoſe parts from which the communication is cut off. More particularly they aſſert, that the fluid ætherial matter of the heavens acts by impulſe on the ſolid matter of the earth; is inſtrumental in every one of its productions; and neceſſary to all the ſtated *phœnomena* of nature. Hence they divide the elements into *active* and *paſſive*; not that they are ſuch by any *inherent* or *eſſential* difference, but that according to the order eſtabliſhed by the divine architect, they are obſerved to ſubſiſt under theſe different relations.

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* See the life of Dr. *John North.* p. 260.

† See *Maclaurin*'s Account of Sir *Iſaac Newton*'s Diſcoveries.

THIS ſort of philoſophy cannot pretend to be *new.* Certain it is, that all the deſcriptions and alluſions in the *ſacred writings* agree to ſuch a ſcheme of nature rather than to any other. And that the moſt ancient heathens were in poſſeſſion of this knowlege, I ſhall take occaſion to ſhew, before I finiſh what I have to ſay upon this ſubject. When it was in their hands, the *active elements* had a principle of *intelligence* aſcribed to them, and were taken for the *Gods that govern the world.* But with thoſe who are taught, that the *true God* is diſtinct from and above the world of matter, though virtually preſent in it by a providential inſpection and ſuperintendence, it will only ſerve to inlarge their ideas, by ſetting before them the viſible evidence of that divine wiſdom, which, with ſo exquiſite a contrivance, and ſuch a ſimplicity of deſign, hath adapted phyſical *cauſes* to the production of their reſpective effects: it will introduce them to a knowlege of *things*, inſtead of leaving them to founder in a ſet of *hard words*, which as I ſhall hereafter ſhew have not yet been defined, nor ever can be ſo long as the world laſts.

SOMETHING like to this was attempted in the laſt century by *Des-cartes*: but his method of deducing the knowlege of phyſical cauſes *a priori* was very exceptionable. He was ſo fond of being thought an original, that although an univerſal *ſubtile matter* does certainly exiſt, he ſtated the caſe in ſuch a faſhion, as to render it ſuſpected; and having aſſigned a motion to his elements not agreeing with experience, and ſuch as cannot be made ſenſe of, ſo long as *Kepler*'s law is admitted, his *hypotheſis* was eaſily brought into diſrepute. Many of the learned, however, in other countries ſtill endeavour to make the beſt of it; rather becauſe all experiments ſhew them the abſurdity of a vacuum and the inſufficiency of attraction [*], than that they believe the ſyſtem of their maſter to be abſolutely perfect. And here let me obſerve by the way, that where nature is the ſubject of inquiry, no error can be more unfortunate, than that of reaſoning *a priori*. Men have no right to aſſume the character of lawgivers to the works of God, but muſt be content to borrow from them all the laws of their own philoſophy; and till they will condeſcend to do this, there can be nothing but uſeleſs wrangling and diſpute, even in regard to firſt-principles and fundamentals. *Des-cartes* was of opinion, that the world is directed by ſome ſubordinate and mechanical cauſes. In which he ſeems to have been right only by accident; for as to the kind and quality of theſe cauſes, he ſearched no farther than his own brain, and neglected thoſe undeniable phœnomena, with which his cauſes are not to be reconciled.

Sir *Iſaac Newton*, on the other hand, was very diligent in ſtudying thoſe phœnomena, which belong chiefly to the claſs of natural *effects*; in the adjuſting of which he makes a great figure; but unhappily ſolves the whole government of the created world by a *noſtrum*, which hath never yet been underſtood; and in the application of which, he was not very conſiſtent with himſelf, as we ſhall find hereafter.

The followers of *Newton* and *Des-cartes*, having thus admitted ſomething which is arbitrary in the very foundation of their ſchemes; we can never expect to ſee their diſputes brought to any iſſue, ſo long as there are men equally learned and ingenious on both ſides to perpetuate them.

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[*] Couſult *De Gamaches* Aſtron. Phyſ. p. 348 &c. *Regnault*. Entret. Phyſ. Vol. 3. p. 322 &c. *Banieres*. Examen. p. 28. & alibi paſſ. *Le Pluſche*. Hiſt. of the Heavens. Book 2. c. 10. As for the *Abbè Nollet*, he refers us for his ſentiments to the *Abbè le Pluſche*.

While theſe able philoſophers are contending with each other, ſome in the purſuit of fame, and others in the purſuit of truth, without being able to agree where and with whom it is to be found, I ſhould not dare to interpoſe in ſuch a ſubject, unleſs I ſuſpected natural philoſophy to be a much eaſier thing than they have made of it; and ſuch, as a plain man, who only conſults the proper evidence, and pretends to no more wiſdom than the reſt of mankind, may be able to ſtrike ſome light upon. This however cannot be done in ſuch a manner as to be attended with any good effect, till it is firſt determined, whether the operations of nature are immediately owing to mechanical cauſes; or whether they are conducted after a manner unknown to us in empty ſpaces. Thoſe who aſſert the latter are ſuppoſed to do it with *demonſtration* on their ſide. It would be vain therefore to deſcribe the mechaniſm of the world, and deſcend to the conſideration of any particular effects, ſo long as even the general method of ſolving effects by the operation of mechanical agents is thought to be an abſurdity. This method of philoſophiſing is the very thing, againſt which, ſome of the demonſtrations, that have gained moſt credit with the learned, are directly levelled: and the writings of our modern reaſoners, whether metaphyſicians or mathematicians, are ſtored with objections, not only againſt the reality, but even the poſſibility of a *mechanical agency*. To theſe their objections I ſhall now addreſs myſelf particularly, and endeavour to ſhew, that not one amongſt them all is of any force. As to their *prejudices*, I do not undertake to remove them: but leave it to time, and a farther knowlege of things, to wear off all ſuch impreſſions as will not bear to be reaſoned with.

CHAP. II.

A reply to the principal objections in Dr. Clarke's *Letters to Mr.* Leibnitz.

IT will be allowed me, that the celebrated Dr. *Samuel Clarke*, when he undertook to defend the *Newtonian* philoſophy againſt Mr. *Leibnitz*, an able *Carteſian*, underſtood what he was diſputing about, and hath ſaid the beſt that was to be ſaid upon the occaſion. If this ſhould give but little trouble, we have not much to fear from any body elſe. He has brought together ſeveral arguments againſt the doctrine of a general mechaniſm in nature; the firſt of which, if it can be called an argument, conſiſts in barely aſſerting the *impoſſibility* of it. *Certain portions of matter*, ſays he, *are obliged to follow each others motions by an adheſion of parts, which no* mechaniſm *can account for.*[*]

Now that the *parts* of bodies are made to *adhere* together, and ſome of them very ſtrongly, is an undoubted matter of fact; that *no mechaniſm can account* for this, or that it cannot be occaſioned by the action and preſſure of ſome *mechanical agent*, is what Dr. *Clarke* ought to have *proved:* inſtead of which, he takes it for granted; and would put the labouring oar into the hands of his adverſaries. For, having mentioned this opinion of Mr. *Leibnitz*, that the continuation of motion in the heavenly bodies, the formation of planets, &c. are mechanical operations: *whoever*, ſays he, *entertains this opinion, is, I think, obliged* in reaſon *to be able to explain* particularly, *by what laws* of mechaniſm

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[*] Collection of papers between Mr. *Leibnitz* and Dr. *Clarke*, p. 363.

the planets and comets can continue to move in the orbs *they do thro'* unreſiſting ſpaces; *and by what mechanical laws both plants and animals are formed.* *

But this is the ſtrangeſt taſk that ever was impoſed ſince the labours of *Hercules:* for we muſt firſt allow this author to *empty* the celeſtial ſpaces of all matter, and then fall to work to account for the motion of the planets in theſe ſpaces by *mechaniſm:* and we muſt do it *particularly*, ſo as to give general ſatisfaction, without failing in a ſingle article. If theſe ſpaces be void of all *reſiſting* matter, it follows of courſe that they are alſo void of all *impelling* matter; for the fluid that cannot reſiſt in ſome caſes, will never be able to impel in others. So that this *reaſonable* demand, as he thinks it, is no other than this —— we are to explain all things *mechanically*; but then we muſt take care to do it *without mechaniſm*. It is not the method of a fair diſputant, to require an adverſary to diſarm himſelf, and to ſubmit to ſuch a ſtate of the caſe, as will render it impoſſible for him to ſucceed, and prove him to be very weak indeed, if under ſuch circumſtances he ſhould ever ſet about it.

Besides, there is a great want of perſpicuity in Dr. *Clarke*'s way of expreſſing himſelf; it being hard to conceive, how the motion of a planet or a comet can be continued *by* any *law* of mechaniſm. *By* ſome mechanical *cauſe*, and *according* to ſome particular *law*, it may perhaps be continued: but his expreſſion ſuppoſes, that the law, *after* which any motion is continued, is itſelf the *cauſe* of its continuance. The word *law*, in a phyſical ſenſe, means nothing more than that degree or *proportion*, according to which ſome cauſe is obſerved to produce its proper effect; as that of the effect decreaſing as the ſquares of the diſtances increaſe, is the law according to which the cauſe of gravity is obſerved to act. And though I may here ſeem to be criticizing on words, yet whoever examines the affair of *laws*, *cauſes*, *powers*, *principles*, and *qualities*, as they are ſet forth by ſome modern philoſophers of great name, will diſcover no ſmall embaraſſment; of which I could give ſome curious inſtances. The truth is this; being ignorant of phyſical *cauſes*, they have endeavoured to argue ſuch things out of the creation, and have put theſe *laws* into their place; which has produced a ſort of equivocation, very unintelligible to thoſe who are not apprized of it.

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* Collection of papers between Mr. *Leibnitz* and Dr. *Clarke*, p. 363.

If the queſtions abovementioned were rightly put, there would be no ſuch great difficulty in replying to them. Thus, if it be required, what mechanical *cauſe* is preſent in the celeſtial ſpaces, to continue the motions of the planets and comets? our ſenſes tell us, that *light* is diffuſed throughout theſe ſpaces: and we learn from ſeveral experiments, particularly from thoſe of *electricity*, that the matter of light can *impel* and *reſiſt*, and that with a degree of power hardly to be believed but by thoſe who are witneſſes of it. That the heavenly bodies can move in ſpaces filled with this matter, and yet feel no *reſiſtance* from it, is not to be demonſtrated by any phyſical proof. I know very well what is commonly urged to the contrary from the *theory of reſiſtances*, of which, in due order, I hope to give a ſatisfactory account.

If it ſhould alſo be enquired, after what *law* of mechaniſm this *cauſe* will act, the anſwer is eaſy; there being but one law known to us, which a fluid, iſſuing in ſtrait lines from a center to a circumference, can poſſibly obſerve; and it is this, that its force will decreaſe as the angle grows wider; or to ſpeak more ſtrictly, its force will always be inverſely as the ſquare of the diſtance from the center. Dr. *Gregory*, in his elements of aſtronomy, vol. I. p. 506, has a propoſition, wherein he demonſtrates that the quantity of *illumination* on the ſame ſphere, placed at *different diſtances* from the lucid body, is reciprocally as the *ſquares of the diſtances:* and this is ſo well known to every mathematician, that it is needleſs to inſiſt upon it.

Hence it will follow, that if the rays of light, or any other ætherial matter, whether iſſuing *from* the ſun as from a center, or preſſing *toward* the ſun as toward a center, have any ſhare in the motion of the earth and planets, the influence of ſuch an agent will be *reciprocally as the ſquares of the diſtances:* its power will increaſe and decreaſe according to the ſame law, and for the ſame reaſon too, that the quantity of *illumination* does. This law was firſt diſcovered by *Kepler*; and has been greatly advanced by the labours of Sir *Iſaac Newton*. But then I beg the reader to obſerve, it is a geometrical law; and as geometry is not applicable to immaterial eſſences, but only to *matter* and *quantity*, it muſt alſo be a law of matter, that is a *mechanical* law; and if the planets are moved according to a *mechanical law*, it muſt follow that they are moved *by* a *mechanical agent*, be that agent what it will. For it would be abſurd to the laſt degree, to believe that the action of an *immaterial power*, or the immediate influence of God himſelf ſhould be found to *decreaſe by a geometrical rule*, and its force be capable of being *calculated* at various diſtances like the efflux of light from a candle!

Should it likewiſe be aſked, what mechanical *agent* is concerned in the formation, growth, and ſupport of *animals* and *vegetables*; it is very clear from all experiments, that in the common courſe of things, neither a plant nor an animal was ever yet formed or ſupported under the abſence either of *air* or of *heat*; by the latter of which, I would always be underſtood to mean, the *effect of fire.* An egg has *air* * incloſed at one end of it, to be expanded, and made to preſs upon the contents by the *heat* of incubation. And what is ſtill more remarkable, air is found neceſſary, not to the *inſide* only, but alſo to the *outſide* of a ſhell, within which an animal is to be formed; for Mr. *Boyle* obſerved, that the eggs of ſilkworms will not be hatched within an exhauſted receiver, though it be expoſed to the ſun's rays.

WITH regard to *plants*, every common gardener could have informed Dr. *Clarke*, that air and fire have an abſolute dominion over the whole vegetable kingdom; the expence of ſtoves, thermometers, and ventilators, might otherwiſe be ſpared, and the whole buſineſs of gardening tranſacted in a *vacuum.* But this is ſo far from being the caſe, that it is really amazing to ſee, with what an exactneſs the ſeveral tribes of plants agree in their ſubſtance, ſizes, and properties, with the *ſeaſon* and *climate* in which they appear, that is, with the different and unequal diſtributions of heat and cold all over the face of the earth; of which phœnomenon, I ſhall have occaſion to take ſome farther notice in a proper place.

AS to the body of man, the circulation of the blood, and the ſpontaneous motion of the limbs, if it can be ſhewn, that any of theſe motions are carried on without *breath* in the lungs, and *heat* in the veſſels, it will then be time enough to affirm, that they cannot obſerve a mechanical law, or depend on the actions of a material agent. So far as we are able to judge from what appears to us, the circulation of the blood, and all the animal functions, are ſuſtained and carried on by an internal heat, which keeps the blood fluid, and by the external *air* preſſing into the lungs. Theſe ſerve as a pump to draw the blood from the heart, and the air keeps this pump in motion. Thus the air is to the body, what the weight is to a clock; while the heart, with its valves, performs the office of a *pendulum*, to gauge and regulate the circulation. What I have here ſaid in few words, might be confirmed at large from the obſervations and experiments of *Swammerdam*, *Bartholine*, Dr. *Hales*, and others. Were the theory of *animal motion* to be ſtated for us, as that of the planetary motions abovementioned, this author ſhould have ſet us to account mechanically for the motions of a *living* animal from the example of a *dead* one; the motion of the planets, in *unreſiſting ſpaces*, being juſt as unphiloſophical, and as hard to account for, as the circulation of the blood in a dead corps.

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* Cavitatis illius, in obtuſa ovi parte, utilitates oſtendam. *Aërem* intra ſe continet; ideoque utilis eſt ad ovi *ventilationem*; ad pulli perſpirationem, refrigerium, & reſpirationem; ac denique ad loquelam. Unde cavitas illa primo *exigua,* mox *major*, ac demum *maxima* conſpicitur, *Harvey*. de Gen. animal. *Exercit.* LXI.

I MAY obſerve, upon the whole, that the way of reaſoning Dr. *Clarke* hath choſen upon this occaſion, can do no ſervice to any cauſe whatſoever. His deſign is plainly this — to throw ſome difficulties in the way, and then lay the foundation of his own philoſophy in that *ignorance* which is common to us all. For ſuppoſe we are not able fully to accompliſh the taſk he has impoſed, and give ſuch a mechanical ſolution as ſhall be adequate in every inſtance; muſt it be allowed, that there is no mechanical agency, till we are able to explain particularly *how* every one of its effects are brought to paſs? There may be in nature a thouſand examples of a mechanical agency, where the particular *manner* of it hath not yet been diſcovered, nor the ſubject perhaps ever examined with ſuch a view. And in ſome caſes, I ſuppoſe, the contrivance of an omniſcient artiſt may, after all our labour, be above the reach of human obſervation; unleſs the mechanical ſkill of God and man muſt neceſſarily have the ſame limits.

To build a philoſophy on theſe caſes is to begin at the wrong end. The only courſe that can promiſe any tolerable ſucceſs, is to ſet out with the caſes that are well underſtood; and thence argue by analogy, to ſuch as are more remote, and difficult of acceſs. But to begin with the things that are unknown is the way to create difficulties where there were none before: and as we ſhall moſt probably try to make things of a piece, our ignorance *there* will diffuſe itſelf univerſally, and give a mixture of darkneſs to the knowlege we had already obtained.

DR. *Clarke*'s manner of objecting doth alſo give me a fair opportunity of turning the tables upon him; and that, as I am inclined to think, very much to the diſcredit of all his reaſoning. For if it be true, that he who maintains the mechaniſm of the creation, is *obliged in reaſon to be able to explain all* effects in that way, and ſhew how *every thing* is performed mechanically; then it muſt be equally true, that he who maintains the contrary, and rejects the notion of a general mechaniſm, is obliged in reaſon to ſhew, that *nothing* is performed mechanically. For if it can be ſhewn, that mechaniſm prevails in any one inſtance, it will lead us to conclude, that it muſt prevail in every other; upon a bare preſumption, that nature has a wiſe author at the head of it, and is governed by conſiſtent laws, not by ſuch as are capricious and contradictory. The wiſdom of God will be uniform in its operations; and if it works with *natural means* in ſome caſes, and we can be well aſſured of it, I may venture to ſay, it does not work without them in any; thoſe only excepted, wherein the eſtabliſhed œconomy of the world is interrupted by ſome immediate act of divine power, or a miraculous interpoſition. But theſe are more properly the ſubjects of divinity, than of natural philoſophy, which conſiders nature *as it is*, and in its regular courſe; not as it may happen on ſome certain occaſions, and for ſufficient reaſons, to be thrown out of its courſe.

To argue from the abſolute *power* of God, excluſive of his *wiſdom*, and that he is *able* to act by the unmechanical forces of *attraction* &c. would but ill become thoſe, whoſe proper buſineſs it is to ſhew how things *are* done, not how they *might* be done. Without doubt, it would have been poſſible with God to have given man the ſenſe of *ſeeing*, on very different principles from thoſe at preſent eſtabliſhed. The *power* of God wants not the mediation of light, to convey to us a perception of diſtant objects; but his *wiſdom* hath been pleaſed to make uſe of this fluid medium, as the natural inſtrument or phyſical cauſe of viſion. The eye is a compleat piece of optical machinery, perfectly analogous to a *camera obſcura*. The *chryſtalline humour*, lodged near the protuberant part of it, is a double convex *lens* or magnifying glaſs; the *pupil* anſwers to the hole in the window-ſhutter; the *Iris* is a moveable curtain, to enlarge or contract the pupil ſo as to admit a proper quantity of rays; it anſwers the ſame end as the *aperture* in a common teleſcope; and the *retina*, which is an expanſion of the optic nerve upon the back part of the eye, is the ſheet, upon which the images of the objects are properly coloured in miniature. What occaſion for all this *apparatus*, when ſome quality with an hard name *might* have anſwered the end as well?

Is not this alone ſufficient to convince us, that the wiſdom of God hath choſen to act with natural means; that is, with the inſtrumentality of a fluid medium, and matter properly arranged to receive its impreſſions? If this is done in *one* part of the body, my reaſon will be ſuggeſting to me, it is done in *all*; that as the optic nerves are acted upon by a material medium for the purpoſes of viſion, ſo the *lungs* muſt play, the *heart* beat, the *blood* circulate, and life, ſenſe, and motion, be kept up throughout the whole human frame, on the ſame plan of *mechaniſm.*

And if the body of man, which many philoſophers have conſidered as a leſſer world, be of a piece with the greater, as the ſame way of reaſoning, if carried forward, will incline us to ſuppoſe; the motion of that too is kept up by natural means. The ſame fluid medium that gives motion to the lungs, or ſight to the eye, may conduct a planet in its orbit, and produce all the various appearances that have fallen under the obſervation of the moſt induſtrious naturaliſt. As there are no vacuums, no attractions, no repulſions in the human frame, but all is carried on by the impreſſion of *material forces*, there is no reaſon to conclude that theſe *imaginary* principles (for ſuch I ſhall prove them to be) prevail in the planetary regions; but rather, that all things are conducted by a like method even there alſo.

The parallel now before us will ſerve to detect the weakneſs of that common argument againſt a plenum, and a mechanical agency, which is drawn from the doctrine of *reſiſtance.* Some learned men are of opinion, that if the ſyſtem of the world were full of matter, a planet muſt very ſoon loſe its motion. But this argument will make a very indifferent figure when applied to the human body. There, I think, we have a *plenum* undiſputed; and the blood, once in motion, is reſiſted by every artery in the body; the ſum total of which reſiſtance, as *Borelli*[*] has computed it, is almoſt incredible. He makes it equal to 180,000*lb.* Yet this *involuntary* motion continues without any diminution of it's velocity, till the machine is quite worn out, or till the providence of God is pleaſed to put a ſtop to it by ſome ſhorter method.

CAN any man think he impoſes an unſurmountable difficulty upon God, becauſe he can prove, that the fluids of the human body muſt meet with a reſiſtance to their motion? Muſt the frame of man be turned into a *vacuum* upon this account? the fact itſelf is a ſufficient anſwer to all ſuch pretences. And if the blood is not ſtopt in its circulation by the reſiſtance of the ſolids, why ſhould the reſiſtance of a fluid ſtop the circulation of a planet? for doubtleſs, if the divine wiſdom hath contrived a way to overcome this reſiſtance in one inſtance, it may in another; and the argument for a vacuum, deduced from the *neceſſity* for ſuch a thing, will be very weak and inconſequential. But of this, more hereafter.

TO induce us wholly to give up the affair of *mechaniſm*, the author of the papers againſt Mr. *Leibnitz* has added the following conſideration. "That things (ſays he) could "not be *at firſt produced* by *mechaniſm*, is expreſſly allow"ed: and when this is once admitted, why after that ſo "great concern ſhould be ſhewn *to exclude Gods actual go"vernment* out of the world &c. I can no way con"ceive."[†]

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[*] De Mot. Animal. P. II. prop. LXXIII.

[†] Ibid. p. 365.

We have an ambiguity here in the terms, which ought to be removed. For if by *produced* he means *created*, no ſober man, I ſuppoſe, will diſpute that point with him; it being certain, that *creation* was no work of mechaniſm, but a pure act of the will and omnipotence of the creator. If by *production*, he means that *formation* of terreſtrial ſubſtances, plants, and animals, which was ſubſequent to the act of *creation*, it is certain, that in that formation and diſpoſition of God's works ſome *material agents* were employed, even the ſame that operate to this very day. The *natural agency* now in diſpute, was the *firſt* article God thought proper to ſettle in the diſpoſition of the world: *air*, *light*, and the *firmament of heaven*, were firſt prepared and put into action: after that the formation of all other things followed in their proper place.

If Dr. *Clarke* could have ſhewn, that trees and plants were made to grow before there was any *light* or *air* to be inſtrumental in the proceſs, he had done ſomething to the purpoſe: but as far as we can learn, his ſcheme of philoſophy agrees no better with the *origin* of nature, to which he here appeals, than with the preſent frame and conſtitution of it.

As for *excluding God's government out of the world*, if that was the deſign of Mr. *Leibnitz*, he muſt anſwer for it. But it can never follow, that if a *ſecond* cauſe be interpoſed, the *firſt* cauſe is *for that reaſon* excluded: no man would be ſo weak as to affirm that; becauſe every *ſecond* cauſe, as ſuch, muſt depend upon the *firſt*. The author therefore has thought proper to call it an *actual* government; which muſt mean either *immediate* or *real*. If he maintains, that the agency of the divine eſſence is *immediate* in the production of natural effects, which, in the judgment of ſome, is the grand *arcanum* of the modern mathematical philoſophy, it is incumbent upon him firſt to prove, that no ſecond cauſe, created eſſence, or *material agent* is fitted for the purpoſe; which inſtead of being proved is hitherto taken for granted. If he means, that the *real* government or providence of God is excluded; neither will it follow, that his government is leſs *real*, becauſe he rules the world by natural cauſes under the direction of himſelf the ſupreme cauſe. If this be a neceſſary conſequence, the ſcripture itſelf is chargeable with it; and where it inſtructs us, that the *ſun* is made to *rule over the day*, it muſt inſinuate, that the providence of God does not rule over the world.

When we ſpeak of mechanical cauſes as doing any thing in the world, Dr. *Clarke* will immediately take us up, and conclude they are to do it *of themſelves* *, independent of the divine *power* and *wiſdom*; which opinion Mr. *Leibnitz*, with whom he was diſputing, had expreſſly diſclaimed. For my own part, I adhere only to the *matter of fact*; and *that* I know will bear me out againſt all the metaphyſical ſubtilties in the world. But if the reader ſhould be diſtreſſed with any doubts in this matter, only let him remember that matter acts upon matter, not by an *eſſential* but a *mechanical power* i. e. by its *motion:* for in the natural, as in the moral world, we hold that *there is no power but of God.* If this diſtinction be attended to, all that has been ſo induſtriouſly written in defence of *immaterial impulſes* in a *metaphyſical* way by the author of the *enquiry into the nature of the human ſoul*, falls to the ground without any particular confutation.

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* *Ibid.*

CHAP. III.

An Anſwer to a phyſical objection from Sir Iſaac Newton.

I Meet with a third objection, which may be properly termed a phyſical one, and deſerves a particular conſideration. "I have explained (ſays Sir *Iſaac Newton* in the *ſcholium generale* at the concluſion of his *principia)* "the "phœnomena of the heavens and ſea by the force of gravity "— which acts, not proportionably to the *ſurfaces* of the "particles it acts upon, as mechanical cauſes uſe to do, but "in proportion to the quantity of *ſolid matter.*" The ſame thing is ſomewhat differently expreſſed by Dr. *Clarke*, in his notes on *Rohault*'s phyſics. "There are innumerable phœ- "nomena of nature, and eſpecially that principle of *gravi-* "*tation* in all matter, which cannot poſſibly ariſe from the "*impulſe* of bodies; for all impulſe is in proportion to the "ſurfaces; but gravity is always anſwerable to the quantity "of ſolid matter; therefore gravity muſt be attributed to "ſome cauſe which can penetrate the inmoſt ſubſtance of "ſolid matter." P. I. c. 11, & 15.

A perſon who is tolerably converſant with the writings of Sir *Iſaac*, would naturally apprehend, that this aſſertion of Dr. *Clarke* is not conſiſtent with them. He has plainly declared, that "what he calls *attraction* may poſſibly ariſe "from *impulſe*." Dr. *Clarke* on the other hand affirms, that the ſame *attraction* of gravity *cannot ariſe from impulſe*, though Sir *Iſaac*, whoſe philoſophy he was defending, has granted the poſſibility of ſuch a thing. There muſt either be a flat contradiction between them, or ſome diſtinction is wanted with regard to the word *impulſe*, for the clearing up of this difficulty. The ſecret then lies here; the *impulſe* which Dr. *Clarke* denies, is *corporeal* impulſe, and ſhould ariſe from the action of ſome impelling *matter:* whereas that which Sir *Iſaac Newton* allows, is *incorporeal*, if his Commentator Dr. *Clarke*, who muſt be ſuppoſed to have known his mind, has not miſunderſtood him; for thus he has expounded the paſſage—*fieri ſane poteſt ut ea efficiatur impulſu (non utique corporeo*)* "It may be, that this "(attraction) is the effect of *impulſe*, but this impulſe is *not* "*corporeal.*"

The conſequence which every intelligent reader will draw from this doctrine of *incorporeal impulſes*, gave Mr. *Leibnitz* and others occaſion to charge the *Newtonian hypotheſis* with the impiety of making God the *ſoul of the world*, as the heathens of old did. But this matter is not now before me: our buſineſs at preſent is to conſider the force of this objection ſo far only as it is phyſical. It is in fact no more than this—mechanical cauſes uſe to act in proportion to the ſurfaces; but the cauſe of gravity acts in proportion to the quantity of ſolid matter; therefore that cauſe cannot be mechanical.

Thus much is certain, that every mechanical cauſe, which is not ſubtile enough to penetrate the contexture of a ſolid body, will be ſtopt at the ſurface; and the action or force of ſuch a cauſe will be proportionable to the ſurface. If there were in nature *no other* mechanical cauſes, but ſuch as act upon the ſurface, and it could be fairly made out, this objection would be unanſwerable. It ought to have been proved, that there really *are* no other; at leaſt it ſhould have been attempted: yet as far as I can find, it hath not; and I think it never will be for the two following reaſons.

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* *Ubi ſupra.*

FIRST, becauſe there may be in ſome caſes an impelling matter, which is too ſubtil for the obſervation of our bodily ſenſes: and to conclude that there can be no material agency, where it does not diſcover itſelf to the organs of the body, is rather too haſty. If the parts of man's body were of the ſubſtance of *iron*, and put together in the ſame manner, he would probably feel the cauſe of *magnetiſm*, as plainly as he now perceives the heat of the ſun's rays, or the blowing of the wind againſt his face: but then it would be of ſmall uſe, to loſe the motion of the joints, and receive a polar direction in the body, merely for the ſatisfaction of feeling, that the cauſe of magnetiſm is material and mechanical; which perhaps may be diſcovered, to as much ſatisfaction, by a more advantageous method.

MY ſecond reaſon for believing that we are to expect no proof of this negative comes a little cloſer to the point; and it is this, that the oppoſite affirmative is evident from a great variety of experiments; there being in nature ſuch mechanical cauſes, as are able to penetrate the ſolid bulk of bodies, and whoſe action extends to every ſingle particle of which they are compoſed. The rays of *light* can paſs as eaſily through the ſolid ſubſtance of glaſs, if not *more* ſo, than through the open air: and it is plain, their effect on bodies is not regulated by the exterior ſurfaces, becauſe an hollow bubble of glaſs hath the ſame exterior ſurface, whether it be empty, or filled with water; yet the light is well known to take a different courſe through it in theſe two caſes. If a leaf of gold be held up between the eye and the ſun's rays, they are not ſtopt by the ſurface of it, as a blaſt of air would be, but paſs its ſubſtance with great eaſe, and appear as a beautiful green colour on the backſide of the leaf. The electrical fire, when put in motion, will paſs off in a ſtream through the denſeſt bodies, and can *penetrate the inmoſt ſubſtance of their ſolid matter:* the influence therefore of ſuch a material cauſe will neither be confined to the ſurfaces, nor be proportionable to them: and I am willing to think, that if Sir *Iſaac* had lived to ſee ſome wonderful effects of this fluid, diſcovered for the moſt part ſince his death, he would have enlarged his notions very much with regard to the natural power and extent of *mechaniſm.*

THERE is hardly a motion in nature, which this fluid, when applied by a diligent experimentaliſt, is not capable of producing. It will give a *rectilinear* motion in all directions; will produce the motions of *rotation* and *revolution*, as a *common fire* will alſo do. It will keep a body ſuſpended at a certain diſtance in the air, without any viſible cauſe, and make it turn ſwiftly on its axis. It will accelerate vegetation, increaſe the motion of the blood in the arteries, raiſe water into tides; and in a word will ſhew itſelf, as a *natural inſtrument*, to be little leſs than all-ſufficient. Again; *common fire* is a fluid, whoſe impulſe reaches to the ſolid parts of bodies. A ſolid ball of iron will conceive a greater quantity of fire, and be longer in parting with it, than an hollow ſhell of the ſame diameter. Water is enlarged in its dimenſions by the entrance of fire into it; *hot* water being ſpecifically lighter than *cold:* and it is enlarged ſo equally throughout the whole ſubſtance of the fluid, that it is certain the fire muſt agitate every one of its ſolid particles, and by preſſing againſt them in all directions, remove them farther aſunder.

FROM theſe and many other experiments open to common obſervation, it muſt appear to every unprejudiced philoſopher, that nature is furniſhed with a mechanical cauſe, whoſe activity is not confined to the ſurfaces of bodies, but extends to their conſtituent parts, that is, to their *quantity of ſolid matter*.

THE ſagacity of Sir *Iſaac Newton* could not well overlook this; and he ſeems to have apprehended ſuch a thing, having affirmed no more, than that mechanical cauſes *uſe* to act in proportion to the ſurfaces: but unleſs they *always* do ſo, by a neceſſary and invariable rule, the inference, that gravity *cannot* be the effect of ſuch a cauſe, is of no force at all. And there is good encouragement to think, that gravity not only *may* be the effect of a material cauſe, but that it really *is* ſo; and that this cauſe might poſſibly be pointed out, and proved by experiment. But I muſt remember, that I am not now accounting for the difficulties in natural philoſophy, but only removing thoſe objections, which lie in the way to a *phyſical* ſolution of them.

THERE is a *phyſico-mathematical* argument of ſome weight, which ought to be conſidered, before I conclude this chapter. It hath been objected, that *gravity* cannot be owing to any *mechanical* cauſe, from the manner in which ſuch cauſes are obſerved to produce their effect.

THUS, for example, when a ſhip is put in motion before the wind, the *velocity* of the wind, *with reſpect to* the ſhip, will be leſs when the ſhip has *acquired ſome motion*, than when it was at reſt; therefore the accelerations in equal moments of time will be unequal. After the firſt impulſe, the acquired velocity of the body will be ſubducting more and more from the *relative velocity* of the fluid; on which account, the accelerations in equal times will be leſs and leſs, till the reſiſtance the body meets with in its motion, becomes a ballance to the force that moves it; at which point the accelerations wholly ceaſe, and the ſhip thenceforward goes on with an equal pace.

THIS, it muſt be confeſſed, is very different from the manner in which the cauſe of gravity produces its effect: for this cauſe, whatever it may be, *acts inceſſantly or continually, and with the ſame force upon a body that is already in motion, as upon a body that is at reſt; which appears from hence, that it produces equal accelerations in falling bodies in equal times.*[*]

THIS property of gravity is manifeſt from ſome abſtracted mathematical reaſoning, which *Galilæo* confirmed by experiment. If a body ſhould continue to fall during the ſecond moment of time, with the velocity it had acquired at the end of the firſt moment; it ought to fall *twice* as far in the ſecond moment, as it did in the firſt. But it is obſerved to fall *thrice* as far: therefore it has derived from its cauſe in this ſecond moment, another *third* quantity of motion, equal to what it derived from it in the firſt. And this law it will continue to obſerve in all the ſucceeding moments, ſo far as human obſervation is able to follow it.

ACCORDING to the received principles, this argument, as here ſtated, bears very hard upon the mechaniſm of gravity. What I have to offer againſt it is this — that the accelerations of a body, moved by wind or water, are continually decreaſing *only upon this account* — becauſe the velocity of the body, after the firſt impulſe, approaches *ſenſibly nearer* to the velocity of the fluid. If the velocity of the fluid ſhould be ſo great, that the velocity of the body ſhall bear no *ſenſible proportion* to it, the objection will vaniſh. And this obſervation, I humbly apprehend, is applicable to the cauſe of gravity. For if that effect is owing to any *phyſical* cauſe, it will in all probability prove to be the ſame with that which produces ſuch wonderful effects in electricity; the *velocity* of which, is not to be meaſured in any trials we are able to make upon it; and for ought we know, may be as great as that of the *light* in its progreſs from the ſun and planets: ſo that the velocity of a falling body, as far as experiments have gone, will bear no ſenſible proportion to it. Therefore the effect ought to be, ſuch as it is found to be.

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[*] *Maclaurin*'s Phil. Diſcov. p. 241.

MR. *Maclaurin*, from whom I have borrowed this objection, mentions it in very few words, and lays no great ſtreſs upon it. He thought it improper to *determine* any thing from hence *concerning the cauſe of gravity* *. And he ſeems to have judged rightly: for whoever ſhall hence determine, that its cauſe is *not mechanical*, will undertake the proof of a very extraordinary *negative*; ſuch as muſt imply, that he is a compleat maſter of all natural ſcience, acquainted with the utmoſt extent and power of thoſe mechanical cauſes, which were contrived and eſtabliſhed by a wiſdom that comprehendeth all things.

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* *Ibid.*

CHAP. IV.

An Examination of the Argument for a *vacuum*, deduced from *reſiſtance* and the *vis inertiæ* of bodies.

WE are now arrived at that part of the ſubject, where all the admirers of *demonſtration* will expect to ſee me drop; that is, to the doctrine of a *vacuum*, and the *theory of reſiſtances*, upon which it is founded. The learned gentlemen, who object to the ſort of philoſophy I am now recommending, know very well without being reminded of it, that if they have proceeded without evidence in *this* matter, their whole fabric falls to the ground without farther trouble: and if I cannot ſhew that they have, I am willing to own, that all I have yet ſaid, or ſhall hereafter ſay, muſt in their opinion go for nothing.

ALLOWING then that there is a *vacuum* or void ſpace in the world, their argument is very ſhort, and will ſtand thus — bodies are obſerved to have motion in ſuch a ſpace; but that motion cannot be the effect of any material cauſe, no ſuch cauſe being preſent to them.

SHOULD we ſuppoſe this to be true, what a confuſed and heterogeneous mixture of ſolutions will it neceſſarily introduce into all our phyſical diſcourſes? That God does in many caſes govern the world by material agents, and conſerve the motion of bodies by the activity of ſecondary cauſes, is beyond diſpute. The ſupport of animal life by *breath*, the motion of a ſhip before the *wind*, of the ſap in vegetables at the approach of the ſun's light, of the mercury in a barometer by the *preſſure of the air*, of the fluid in a thermometer by the expanding power of *fire*, of bodies impelled and driven off again by the flux and reflux of *electrical æther*, with innumerable other phœnomena of nature, all conſpire to eſtabliſh this plain truth. And if it be an axiom in phyſics, that more cauſes are not employed where fewer will ſuffice, how comes it to paſs, that thoſe agents which confeſſedly miniſter to ſo many and great effects, are not ſufficient for the producing of all? ſhall we allow, that God governs the world by a ſubordinate agency and mechaniſm in ſome caſes, where that agency appears to us; and deny it in others, merely becauſe we have loſt ſight of it, or becauſe it would make againſt us? a philoſophy that labours under this difficulty, and is one while working with a *material* cauſe, and in the next breath with an *immaterial* one, be it ever ſo ingeniouſly put together, will after all be liable to this grand exception, that at beſt it is *inconſiſtent*, and unworthy of God. Every body muſt ſee and know, that there are material cauſes acting in the world; and he that denies it, muſt deny his ſenſes. If theſe cauſes are not ſufficient to perform *all* the ſtated operations of nature, then the creator hath made uſe of ſuch means, as are not proportionable to the end. If the Creator himſelf performs them by the immediate agency of his own ſubſtance, then is there no need of any *other* cauſes; they are all *ſuperfluous*. But that there are other cauſes is abundantly evident; therefore they muſt be capable of anſwering their end, and every material effect will be immediately owing to a material cauſe. What I here ſay is grounded on this reaſonable *poſtulatum*, if it may not rather be called an *axiom*, that the wiſdom of God is *conſiſtent with itſelf* in its operations; and that he wants neither power nor ſkill to avoid the error of inconſiſtency: grant but this, and the argument amounts to a *demonſtration*. I muſt confeſs, it appears to me to be ſo unanſwerable, that if I could not take off the pretended evidence for a *vacuum*, I ſhould nevertheleſs be ſatisfied, that it was a ſophiſm, and impute its whole force to a want of ſkill in myſelf to lay open and detect the fallacy of it. And now let us proceed to give it a particular conſideration.

I HAVE a manuſcript-paper by me from a learned and ingenious gentleman of *Cambridge*, wherein the argument for a *vacuum* is ſtated very cloſely; and he will not be offended with me, if I take the liberty of ſetting it down in his own words; for I know how to honour a man of parts and diligence, though we may happen to differ in ſome of our ſentiments.

" You will hardly (ſays he) deny the *vis inertiæ* of mat-" ter, which Sir *Iſaac Newton*, and every author, but the " *materialiſts* think demonſtrably eſſential thereto, and pro-" portionable to its quantity; and therefore, that it muſt " hold equally in the moſt *ſubtil æther*, as in the groſſeſt " matter. Hence it follows, from the *different degrees of re-" ſiſtance* to bodies moving in different mediums, that equal " portions of different mediums contain different degrees of " *vis inertiæ*, and conſequently different *quantities of matter*. " But how can different quantities of matter be contained in " equal bulks, without ſuppoſing *vacuities*, at leaſt in one " of them? No *ſubtil æther*, pervading the pores of the " groſſer medium, will ſolve the difficulty; becauſe ſuch an " æther muſt itſelf be *more porous* than the groſſer medium, " elſe through its *vis inertiæ* it would cauſe an *equal degree* " *of reſiſtance*, contrary to fact and experience. Now what " can this poroſity of the æther be, but *interſtitial vacuities?* " muſt we invent another æther to pervade the pores of the " former, then another, and ſo on, till all the pores be fill-" ed? But this only drives us again upon the difficulty we " have been endeavouring to ſhun; namely, that all bodies " are *equally denſe*, and ought *equally to reſiſt the motion* of " other bodies through them. This, allowing the *vis inertiæ* " of matter to be eſſentially proportionable to its quantity, " is a *ſtrict demonſtration* of an interſtitial *vacuum:* and " therefore difficulties ſtarted againſt it, though we could not " ſolve them, ought not to move us."

We are now poſſeſſed of the objection in its full force. All matter, from its *vis inertiæ*, or a natural indiſpoſition to change its place, muſt give a reſiſtance to motion in proportion to its quantity: and as we find a different degree of reſiſtance to bodies moving in different mediums, there muſt be different quantities of matter in equal ſpaces; and conſequently there is juſt ſo much *more* of vacuum, or abſence of matter, in one of the ſpaces, as there is *leſs* of reſiſtance: where there is *no reſiſtance*, there will be *no matter:* ſo that we muſt either correct the modern doctrine of the *vis inertiæ*, or allow this to be, what Sir *Iſaac* himſelf hath called it — *demonſtratio vacui*. As the *vis inertiæ* is a principle of ſo much conſequence, I am obliged to enter upon an experimental enquiry into the nature of it; in the progreſs of which, I think it will appear, that ſuch an enquiry was never made by Sir *Iſaac* himſelf, nor by this ingenious gentleman; who will find he has taken up with a principle, which he never gave himſelf the trouble to examine. For after all that can be ſaid, *experiment* muſt be the teſt; and to that I ſhall appeal for the truth of what I am going to offer.

WE find then, that if a body be at reſt, a certain force is required to remove it out of its place; and this force is ſuppoſed to be neceſſary only on account of a *vis inertiæ* in the body: for which reaſon, the force required muſt increaſe, as *the quantity of matter* increaſes in the body to be removed. All this will be true, if the *vis inertiæ* is true: but it is contrary to fact. Let us ſuppoſe this body to be of a pound weight, and ſuſpended by a line, ſo that on occaſion it may vibrate as a pendulum. If you would move this body in a direction *upward*, the force required muſt be ſuperior to a pound; if ſideway, in the ſegment of a circle, of which the point of ſuſpenſion is the center, a much leſs force will do the buſineſs; and this force being the true index of the *vis inertiæ*, if that be found to alter, though the *quantity of matter* be ſtill the *ſame*, it proves that the *vis inertiæ* is a changeable thing, depending on ſome certain circumſtances which muſt be taken into the account. And it will appear, that if you can calculate the force which the action of gravity will have upon the body, when elevated to any angle, you will then know what force is requiſite to overcome its *vis inertiæ* or indiſpoſition to motion.

If the ſame body be taken in the hand and left *at reſt* in the air, no force at all is required to put it in motion *downward*; for the cauſe of gravity immediately ſets it a going in its proper direction. So that, *cæteris paribus*, the *vis inertiæ* in all bodies, being more or leſs, juſt as you concur with or contradict the action of gravity upon them, ſeems *in fact* to be no other than a conſequence of their gravity.

When we attempt to give a motion to a body different from that of gravity, we find it already pre-engaged by a determination toward the earth's center: and this natural force is making its effort every moment againſt any foreign force that can be applied to it; to which it is owing, that projectiles, inſtead of proceeding in a ſtrait line, deſcribe a parabolic curve. If gravity and the *vis inertiæ* were things eſſentially different, and independent of one another, *each of them* muſt occaſion a reſiſtance proportionable to the quantity of matter; and the *whole* reſiſtance, as diſcoverable by experiment, would be the *ſum* of two different reſiſtances, the one proceeding from the cauſe of gravity, the other from the *vis inertiæ*. But I am fully perſuaded, that in all entire or detached bodies, we ſhall diſcover no reſiſtance to a change of place, but juſt ſo much as ought to proceed from the action of gravity upon them, and no more.

If this be true, if the *vis inertiæ* be only the conſequence of another principle, two corollaries will ariſe, ſufficient to diſpatch all the argumentative part of the above-demonſtration. For then it will follow, that if we can alter the ſtate of a body in reſpect of its gravity, or its natural tendency *downward*, we ſhall, at the ſame time, alter its ſtate in reſpect of its *vis inertiæ*, or natural indiſpoſition to move when left at reſt: the truth of which will appear from an eaſy experiment.

Take a light glaſs bubble, and load it inwardly with mercury or any other heavy ſubſtance, till it is preciſely of the ſame ſpecific gravity with water. This done, we will ſuppoſe it to weigh two ounces. Let it now be ſuſpended by an hair to the arm of a ballance, and laid at reſt upon a table: if you would raiſe it from thence, and give it a motion upward, you muſt charge the other end with a weight ſome ſmall matter above two ounces; which may ſtand for the force requiſite to overcome its *vis inertiæ*. Let the body then be placed near the bottom of a veſſel filled with water; in which poſition it will remain at reſt: but if you would now give it motion in the ſame direction as before, it may be done with a ſingle grain, that is, with only one thouſandth part of the force required in the former caſe. The reaſon of this ſeeming paradox is this; the motion given does really coincide with that of gravity, though in appearance it contradicts it. For the body being of equal weight with an equal bulk of water, when the body has moved out of the ſpace it occupied at reſt, an equal bulk of water, through the action of gravity upon it, has deſcended into that ſpace; and if we put 1000 for the force neceſſary to raiſe the body, and 1000 for the force of the ſubſiding water, the difference between theſe two leaves a remainder for the *vis inertiæ* = 0. Some quantity however indefinitely ſmall muſt be allowed to produce an *inequality* between the body and the water; for where all things are equal, no motion can enſue. But how much the *vis inertiæ* has to do in this experiment, I leave to be determined by better judges, when they have conſidered it. It may likewiſe be added, that after the bubble has been moved by a force equal only to a *ſingle grain* through a ſpace of water equal to itſelf, *twice as much matter has been put in motion* thereby, as would have been moved in a vacuum by a force ſomewhat ſuperior to *two ounces*, becauſe the bubble has diſplaced a quantity of water equal in weight to itſelf; and water *reſiſts* a moving body nearly a thouſand times more than air. But how can all this be poſſible, if an *indiſpoſition to motion be eſſentially proportionable to the quantity of matter?*

MY ſecond corollary applies itſelf directly to the demonſtration. As the *vis inertiæ* is a neceſſary conſequence of gravity, if there be any fluid, be it what it will, which acts as the *cauſe* of gravity, that fluid muſt itſelf be void of gravity, *conſidered as an effect*, and conſequently of that reſiſtance which has been aſcribed to the *vis inertiæ*. To ſay then, that the *vis inertiæ muſt hold equally in the moſt ſubtil æther as in the groſſeſt matter*, and that from the different degrees of weight or reſiſtance, *different quantities of matter are contained in equal ſpaces*, is to beg the queſtion, that gravity has no material cauſe. But it would be unfair, to demonſtrate that it has none, merely by attributing to it ſuch a property, as from its nature and office it cannot poſſibly have.

It is incumbent therefore on all thoſe, who would build a philoſophy on the *vis inertiæ*, firſt to ſhew us what it is, and to prove by ſome experiment, that there really is ſuch an *original* principle in matter, to be diſcovered *apart*, and *independent* of every other principle at preſent eſtabliſhed in nature, before they can raiſe from it one ſingle conjecture, much leſs a demonſtration. I ſay, of *every* other principle: for a reſiſtance to motion may be occaſioned by more principles than one. A maſs of iron or ſtone, firſt examined with reſpect to the principle of *gravity*, then to that of *coheſion*, or the application of its conſtituent parts to one another, will teach us, that the *whole* quantity may be put in motion with reſpect to the earth's center, much more eaſily than *half* the quantity can be moved with reſpect to the other half: ſo that if the force with which ſome ſolid bodies cohere, were to take place in matter, as univerſally as gravity now does; we might compute the *vis inertiæ* to be ten thouſand times as great as it is, becauſe we ſhould oppoſe the coheſion of bodies, where we now oppoſe their gravity.

Were all matter at reſt, and the action of the elements made to ceaſe, ſo that not a ſingle particle of matter ſhould have any determination to one ſort of motion rather than to another, that would be the time to make an experiment on the *vis inertiæ*. But this principle, ſo far as it is ſubjected to examination under the preſent œconomy of the world, is a thing unfixed and conſequential, not uniform and independent, as the mathematicians have ſuppoſed; whoſe greateſt misfortune it hath been, not to conſider things *as they are*, but to feign an arbitrary and abſtracted ſtate of matter, and thence to argue upon it in its dependent ſtate;

when they are really more different, than the ore of a metal depoſited in the earth, from the ſame metal formed into the wheels of a clock. And what is much more offenſive, the ſame philoſophy which has given to matter an *indifference* to motion by the *vis inertiæ*, has alſo given it an *inclination* to motion by the virtue of *attraction*; both of them *inherent* (as ſhall be hereafter ſhewn) in the ſame particles. The former of theſe does indeed ſeem oppoſite to *materialiſm*; but the latter has ſo ſtrong a reliſh of it, that a friend to the principles of *Spinoza* hath blended them both together [*]. And even Dr. *Derham*, an undiſguiſed and well-deſigning author, has granted as much as *Epicurus* himſelf would have required of him. It was his opinion, that in *the firſt production of matter*, the great author *of all things INSPIRITED the* materials *of which the world conſiſts with ſuch an* active quality, *as ſerves to preſerve the globes entire, and enables them to revolve about their centres.*[†] If this paſſage does not allow to matter a power of directing itſelf, and conſerving its own motions, I know not what to make of it. But it is no concern of mine, ſo I return to the argument; leaving it to thoſe who pretend to have renounced *materialiſm*, to reconcile their own conjunct doctrines of *inert matter*, and *inſpirited materials!*

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[*] See the *Phyſical* paragraphs in a piece entitled an *Eſſay on Spirit.*

[†] Aſtro-theol. p. 148.

CHAP. V.

The argument from reſiſtance proved to be an abſurdity; as it implies, that the cauſe of motion muſt reſiſt the motion which it cauſes. A plain experiment to illuſtrate and confirm the author's reaſoning.

THUS much, I think, may ſuffice to ſhew, that the celebrated demonſtration of a *vacuum* has *ſet out* wrong. It will be as eaſy to prove, even waving all that has been ſaid on the *vis inertiæ*, that it has *concluded* wrong; if the *relation between a moving body and a reſiſting medium* be rightly underſtood.

WHEN a pendulum is made to ſwing in *air*, *water*, or *mercury*, the reſiſtance it meets with is greater, as the medium is denſer: and as a plenum of æther, ſuch as the mechanical philoſophy requires, would be more denſe than any other fluid, its reſiſtance, they ſay, muſt be greater: no motion could poſſibly continue in it. But then as motion is obſerved to continue in the heavens, without any *ſenſible diminution*, there can be no reſiſtance in the heavenly ſpaces, and conſequently no matter of ſufficient denſity to occaſion it.

THIS was Sir *Iſaac Newton*'s way of computing reſiſtances, and the uſe he made of them when computed. That we may ſee whether this doctrine agrees with experience, let us ſuppoſe a ſhip, with its ſails ſpread, to be in motion before the wind: every body muſt allow me, that if the wind were to keep its direction, and the ſhip to have an open ſea, it would go quite round the globe; and for the ſame reaſon that it makes one revolution, it would make another, and ſo on *ad infinitum.* Are we to ſay, that the *air*, in which it moves, is an *unreſiſting medium?* we ought to ſay this, if the demonſtration abovementioned really is what it pretends to be. But the truth is, a medium may, *in its nature*, be a reſiſting one, and yet *in fact* give no ſuch reſiſtance, as ſhall be any impediment to a body moving in it. For let any perſon tell me, how much reſiſtance the ſhip receives from the air in this caſe? the anſwer muſt be,—leſs than none: the reſiſtance here is a negative quantity; and the ſhip is ſo far from *loſing* its motion, that it is continually *receiving* it, as it paſſes through the air; yet it would be falſe to affirm of air in general, that it is not a reſiſting medium. As to the *water* the ſhip ſails upon, this being not the *cauſe* of its motion, will ſerve to retard it; but as the continued impulſe of the air behind, is ſuperior to the ſum of all the following reſiſtances, 1ſt, of the *air before*, 2dly, of the *water* the ſhip ſails upon, and 3dly, of the *cauſe of gravity* which is continually acting upon it; the motion will continue notwithſtanding theſe impediments.

WERE it to be laid down as a general rule from this particular inſtance, that *water* reſiſts motion, but *air* does not; neither will this coincide with experience. A cork, or any other light body, thrown upon the ſtream of a ſluice or floodgate, will be carried off with it; and as it is common for a conſiderable part of the water to return again upon the ſtream in a curve, if it be obſtructed by the banks, and have but a narrow outlet, the cork may come about with it, and compleat its revolutions, ſo long as the cauſe continues to act upon it. The water gives no more reſiſtance in this caſe, than the air did in the other: and thus it will happen univerſally, that every fluid, where it is the *cauſe of motion*, will not be found in that caſe to give any *reſiſtance*, be its quantity of matter great or ſmall.

WE are now prepared to return to the pendulum. If it vibrates in *air*, the air will retard its motion; and there is a good reaſon why it ſhould do ſo, for air is not the *cauſe* of its motion. If in *water*, neither is that the cauſe of its motion; and it will give a greater reſiſtance to it in proportion to its quantity of matter, that is, in proportion to the action of gravity upon it. If in *quickſilver*, it will meet with a ſtill greater reſiſtance, for the ſame reaſons. But if there be any elementary æther, acting as the natural *cauſe of gravity* in bodies; it is juſt as abſurd, to ſearch for the reſiſtance of *ſuch a fluid*, from the motion of a *falling body*; as for that of the *air*, from the motion of a ſhip that ſails by it; or for that of water, from the motion of bodies carried down by a current of it. If one philoſopher may conclude, that gravity cannot be owing to any material fluid, becauſe he has found, that this fluid does not *reſiſt* a *gravitating body*; may not another demonſtrate with equal truth, that a ſhip cannot ſail by the action of the air upon it, becauſe he finds, from the niceſt obſervations, that the air does not *deprive* it of its motion?

LEST the reader ſhould have ſuſpected me of a deſign to prejudice him beforehand, and to inject ſcruples through a want of better arguments; I did not obſerve at the beginning of this diſquiſition, that Sir *Iſaac* had drawn two oppoſite concluſions from a capital experiment, relating to the affair now before us, but it will be proper juſt to mention it in this place. Having cauſed an empty wooden box to vibrate as a pendulum, he loaded the ſame box with 77 times its own weight of metal; and in this latter caſe found the motion to be retarded more than it ought to have been by the theory. In two different editions of his philoſophy, he imputes this to two different cauſes, without the leaſt hint or apology to his readers for ſuch an important change in his opinion. In that of 1687 he accounts for this, from an increaſe in the *reſiſtance of the air*, occaſioned by a ſwifter motion in the heavier pendulum: and has demonſtrated elſewhere, that the reſiſtance of a fluid to a body moving in it, muſt increaſe in a *duplicate ratio* * of the body's velocity; but this conſideration hath no place here. In that of 1726, he imputes this ſame effect, without any repetition of the experiment, to the reſiſtance of a *ſubtil medium* againſt the ſolid parts of the incloſed metal; and mentions not a word about the *reſiſtance of the air*. But herein, it ſeems, he corrected his philoſophy not for the better, it being abſurd, that the reſiſtance of a *ſubtil æther* ſhould be diſcovered in ſuch a caſe as this.

THIS great man ſeems to have laid it down as the foundation of theſe conjectures (for I hope they are not both *demonſtrations)* that an experiment, which requires machinery, can be performed abſolutely without friction; the contrary to which is well known to every mechanic. It is reaſonable to think therefore that the friction between the hook and ring, on which his pendulum ſwung, muſt have been ſomewhat increaſed, when the ball was loaded with a weight 77 times greater; and the difference he found, was no greater than might ariſe from ſuch an impediment, though the inſtrument were ever ſo perfect. It is hard to ſay, how a man of genius, as he certainly was, could throw a plain experiment into two ſuch different ſhapes, neither of which are agreeable to reaſon. Perhaps he thought it would ſuit better with the principles he was endeavouring to eſtabliſh, not altogether to deny the exiſtence of a ſubtil æther, as he did at firſt, for that would have been too much; but rather to enſure his philoſophy, and keep this æther from breaking in upon his ſyſtem, by imputing to it a degree of *reſiſtance*. Whether the learned will conſider of theſe things, I cannot pretend to judge; in time perhaps they may: but for a while, I preſume, he that ventures to interpoſe, muſt be content to let the reproach fall upon himſelf. There was a time when men had given up their underſtandings to the logic of the ſchools * and the quirks of *Ariſtotle*; and woe was to the man, who dared to publiſh a ſuſpicion againſt them. That faſhion is now exploded, and we are all enſlaved to the pretences of a *mathematic* certainty. But if the doctrine of a vacuum is really weak and without foundation, this faſhion will have its period like the former, and we ſhall be reſtored again to the enjoyment of our philoſophical rights and liberties.

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* The reſiſtance a body meets with from a medium, is as the velocity of the body, and the ſpace of the medium paſſed through by it, multiplied into each other. But that ſpace will always be as the velocity; therefore the reſiſtance is, as the velocity multiplied into itſelf, that is, as the *ſquare of the velocity*.

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* I will give a ſpecimen of their *manner* pertinent to the ſubject we are upon. It is a *logical demonſtration* of a *vacuum*, extracted from *Lib.* 4. c. 6. of *Ariſtotle*'s Phyſics. Ου γαρ αν δοκειη ειναι κινησις, ει μη ἦ κενον· το γαρ πληρες αδυνατον ειναι δεξασθαι· ει δε δεξαιτο· και εϛι δυω εν τω αυτω, &c. *If there be no* vacuum, *there can be no* loco-motion. *For a ſpace already full cannot receive any thing into it*; *if it did, there would be two bodies in the ſame place*; *which is an abſurdity* Some of his Commentators put it thus — probatur aſſumptio; quia corpus quod locum mutat, vel inani ſpatio excipitur, vel pleno: ſi inani, habetur propoſitum: ſi pleno, ſequitur duo corpora ſeſe permeare —— "*The aſſumption is thus proved*; *becauſe a body that changes its place, is received either into a ſpace* full *of matter, or into one that is* empty: *if into an empty ſpace, the point is proved*; *if into a full ſpace, then it follows that two bodies muſt penetrate one another's dimenſions.*" And *Ariſtotle* tells us of one *Meliſſus*, an ancient ſophiſt, who being reduced to the laſt extremity by the force of this miſerable argument and determined not to admit a *vacuum*, denied the reality of motion, and held the univerſe to be immoveable. Had this philoſopher truſted to experiments inſtead of logic, he might have ſilenced his adverſaries with very little trouble. For if a bullet be put into a bottle, quite full of water, and cloſe ſtopt down, we have a ſpace filled with an *incompreſſible fluid*; which conſtitutes as good a plenum as need be deſired; yet upon inverting the bottle, we find the bullet can move from the top to the bottom, or from one ſide to the other, as freely as if the bottle were empty. Does it move into an empty ſpace, or into a full one? why truly, into neither; for the bullet and the fluid *change places* with one another, ſo that the motion is not hindred, though the ſpace is always full of matter.

It appears then, that the *vis inertiæ* of matter, under the preſent conſtitution of natural things, is no fit principle for a philoſopher to begin with; and that even ſuppoſing ſuch a principle, I ſay, ſuppoſing ſuch a principle, yet to argue from that to *phyſical cauſes* is an abſurdity: for when any fluid matter becomes a *cauſe of motion*, the caſe is quite altered; and its *reſiſtance*, be it ever ſo great in *other caſes*, will be of no account in *this*. The gentlemen who have reaſoned from this principle, have never once attempted to inquire, what will be the caſe, where matter *gives motion* to other matter; but taking it for granted, that the great author of nature has created a ſet of elements, for no ſingle purpoſe, but to obſtruct bodies in motion, have drawn themſelves into the palpable abſurdity of proving by a mathematical demonſtration, that a matter of fact is an impoſſibility. Of which, if any doubt ſhould yet remain, I will ſubjoin the following experiment, with a few ſhort reflexions upon it.

At the extremities of a ſteel rod of two feet in length, let two lamps of thin glaſs of a ſpherical figure (or any other that the operator chuſes) be ſuſpended as in the figure, (ſee plate 1. fig. 1.) Over theſe lamps let there be two vanes of plate-braſs placed with contrary aſpects, and inclined to about half a right angle. The rod thus furniſhed is to be poiſed by means of a cap fixed to the middle of it, on the point of a needle, ſupported by a foot and pillar. As ſoon as the lamps are lighted, the machine will begin to turn upon its centre, making ſeveral revolutions in a minute, and will continue thus to move, ſo long as the lights continue burning: and ſuppoſing the lights to have a perpetual ſupply,

ply, the conſequence of that would be a *perpetual motion* in the machine.

We will imagine a mathematical philoſopher to be contemplating this ſight at a diſtance. If his eye is in the plane of the motion, the lights will appear to move backward and forward in a ſtrait line: but as their velocity will be apparently unequal in different parts of the line, he will conclude they move in a curve; and by conſidering attentively in what proportion the apparent motion is accelerated and retarded, he will diſcover that curve to be a perfect circle. Thus far he argues as an *aſtronomer* and *geometrician:* therefore his concluſion will be undeniable; and I mention this to ſhew the diſtinction between *aſtronomy* and *phyſics*. But in the next place, he proceeds to inveſtigate the *cauſes* of this motion: and having found, as he imagines, that all matter muſt *reſiſt* motion in proportion to its quantity; if the lights circulate in a *reſiſting medium*, their velocity he concludes muſt be diminiſhed, and by degrees be utterly loſt. But having obſerved for ſeveral days, and he might do it for as many hundred years, that they continue to move with the ſame velocity, and compleat their periods exactly in the ſame time, as when he firſt began to make his obſervations; he concludes, they muſt move in an *unreſiſting ſpace:*[*] and having diſpatched all *material impulſes* out of the way, aſſigns a *projectile* force as the cauſe of their *progreſſive* motion, and an *attractive* force, exactly counter-ballanced to it (that is, equal to the *verſed ſine* of an arc deſcribed in a given time) as the cauſe of their *circular* motion: affirming at the ſame time, that theſe two forces are ſufficient to account for all the phœnomena, and will do it *better than any material medium whatſoever* [*]; and that in the whole courſe of this reaſoning, he has not *made one ſuppoſition* [†]. The ſum of this evidence is given us in a few words by that ſkilful mathematician Dr. *Cotes*, in his preface to the *Principia*: *Corpora progrediendo motum ſuum fluido ambienti communicant; communicando amittunt; amittendo retardantur.* — "Bodies in their progreſſion *communicate* their motion to "the ſurrounding fluid; what they communicate they *loſe*; "and by loſing it they are *retarded*." Then he undertakes to prove, that motion cannot be kept up by the impulſe of any fluid whatſoever, but upon the following condition — *niſi velocitas abſoluta fluidi recurrentis duplo major fuerit quam velocitas abſoluta fluidi propulſi*; *quod fieri nequit* — that is, "unleſs the abſolute velocity of the fluid which falls "in *behind*, be twice as great as the abſolute velocity of the "fluid driven away *before*; which cannot poſſibly be [‡]." We have in theſe words the whole ſtrength of the *Newtonian hypotheſis*; this is its fundamental argument: yet if it be compared with the preſent experiment, there is not one word in it, from the beginning to the end, that will hold true. For, in the firſt place, theſe two bodies cannot, in Dr. *Cotes*'s ſenſe, *communicate their motion* to the ſurrounding fluid, becauſe they were left *at reſt*, and had *none to communicate*. They are no *projectiles*: and the mathematical philoſophy having made *projection* its firſt principle of motion, is entirely to ſeek, where *that* is out of the queſtion.

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[*] "Againſt filling the heavens with fluid mediums, unleſs they be exceeding rare, a great "objection ariſes from the regular and very laſting motions of the planets and comets — thence "it is manifeſt, that the heavens are void of all ſenſible reſiſtance, and by conſequence of all "ſenſible matter." *Opt.* Q. 28.

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[*] "The motion of the planets and comets being *better* explained without it." *Newt*. Opt. Qu. 28.

[†] "Hypotheſes non fingo." *Princip. ad fin.*

[‡] This, by the way, will prove, that when a cork ſwims down a ſtream, the water *muſt* run twice as faſt *behind* as it does *before* it.

Secondly, as they communicated no motion, they *loſe* none; but are continually receiving a freſh and equable ſupply of it: for which reaſon, thirdly, they are not *retarded*; but are poſſeſſed of a motion, which, in theory, is abſolutely a *perpetual* one. Whence it appears, fourthly, that the *fieri nequit*, to which Dr. *Cotes* hath reduced himſelf, hath affirmed too much, and confuted itſelf. For if the *preſſure* of the ſurrounding fluid be greater on the illuminated ſide of the vanes, than its reſiſtance on the oppoſite ſides; that *inequality of preſſure* will neceſſarily produce a motion toward the weaker ſide; and for the ſame reaſon that it produces, it would alſo conſerve the motion for ever. — Fifthly and laſtly, the well-known inference from a *continuance of motion* is worſt of all: for if the machine were placed in a *vacuum*, that is, in a ſpace void of *air*, the lights would expire, and *motion* be at an end. A ſmall hint will be ſufficient here by way of application; only let it be remembered, that the lights we uſe for experiment-ſake, will decay in ſpite of us; whereas that lamp, which God hath lighted up in the world, never goes out. And he that can retain ſo mean an opinion of the *ſun*, that *marvellous inſtrument* of the divine wiſdom, as to ſuppoſe it acts, not by the emanation of its *light*, but by its *quantity of ſolid matter*, ſhould *put out* the two lamps and *weigh* them, in order to account for this experiment. If this is not enough to convince the ingenuous part of our mathematicians, that their ſcience hath been miſapplied, and that their way of reaſoning upon *phyſical cauſes* is fundamentally wrong; they muſt be left to philoſophize *ſuo more:* if they are deaf to the evidence of *nature*, it is hardly to be expected they will yield to any remonſtrances of mine.

As the doctrine of a *vacuum*, and the *theory of reſiſtances*, are points of ſo much importance, I have tried to be as particular as the cauſe required, and as methodical and perſpicuous as my ſmall abilities would allow me. If there be a conſiderable defect in any of my deductions, I ſhall be very glad to be better informed: and perhaps ſome of the followers of Sir *Iſaac Newton* may ſhew ſo much candour and humility toward a man who *means well*, as not to think him too inſignificant to be taken notice of.

CHAP. VI.

A geometrical argument for a vacuum examined and refuted.

EXPERIMENT and logic having both failed in the demonſtration of a vacuum; let us ſee what ſtreſs is to be laid on *geometry* in the caſe before us: for we have been ſo ſtunned of late years with its praiſes, that it will be neither prudent nor handſome to overlook its pretenſions. Dr. *Keil* the aſtronomical profeſſor was a very eminent geometrician, and as ſtrenuous an advocate in behalf of a vacuum. To convince us that there really is ſuch a thing in nature, he offers the following demonſtration, which I fix upon, becauſe it has the author's own commendation, who calls it an *invincible* one, as the reader will find in the 17th page of his *philoſophical lectures*. He deſires us to "ſuppoſe all the matter in "the univerſe to be amaſſed into two ſpheres, which may "be repreſented by two circles, whoſe centers are A and B. "If theſe ſpheres touch one another, it is neceſſary that they "touch one another in one point only by the elements of "geometry — and therefore there will be betwixt the other "points of theſe ſpheres a certain and determinate ſpace not "replete with matter." Hence the author concludes "that "there is *in reality* a ſpace diſtinct from all body." p. 19.

THIS is Dr. *Keil*'s *invincible* demonſtration: for the erecting of which, you are only to allow this ſmall ſuppoſition, that the omnipotence of God might poſſibly accumulate all the matter of the univerſe into two ſolid ſpheres; and becauſe there *would be* in this caſe a ſpace void of all matter; it follows in his way of reaſoning, that there *really* is ſuch a ſpace. This author ſeems to have been ſo full of geometry, that there was no room for any logic; elſe he might have picked up enough of it at *Oxford* to have taught him — *a poſſe ad eſſe non valet conſequentia*. Beſides, it is the proper buſineſs of a philoſopher to conſider the operations of nature, as nature is now conſtructed; where I apprehend, he will find work enough without making a new world, or ſhuffling the old one into a new ſhape. But Dr. *Keil* imagined it would edifie us more, to tell us what ſtrange things would happen, if the world were all taken to pieces, and put together again in ſuch a form, as could anſwer no one purpoſe of the creation.

IF a queſtion had been put to him, whether the motion of a *pendulum* in a clock is preſerved by the action of occult virtues propagated through void ſpaces from one wheel to another, or by a contact and bearing of the parts upon one another from the weight to the pendulum; he might have demonſtrated the former *invincibly*, by ſuppoſing, that if the matter of the whole machine were melted down, and made up again into a couple of wheels, their circumferences could touch one another but in a ſingle point; and a man might make a clock upon this principle, with juſt as much accuracy as he can philoſophize upon the other. He that will impartially conſider this, and many other geometrical arguments of the ſame complexion (with which I could fill a book if it were neceſſary) will not be very haſty to believe any propoſition, becauſe it is *ſaid* to be ſupported by mathematical evidence; which though it be ſtrong in its proper place, and undeniable if conſidered in the abſtract, is nevertheleſs, when miſapplied, juſt as weak as any other ſort of evidence that is equally impertinent. The lovers of mathematical learning, like other men, are too fond of magnifying their favourite ſcience; and will be introducing it, where it can add no light, but will ſpread an air of myſtery and darkneſs over a ſubject, in itſelf plain and intelligible enough. Such unſeaſonable applications of it are ſo far from advancing its credit with ſober men, that they are in danger of bringing a pleaſant and profitable branch of learning into contempt.

IT was an obſervation of the excellent Lord *Bacon*, whoſe judgment in theſe matters hath never yet been called in queſtion — *optime cedit inquiſitio naturalis, quando phyſicum terminatur in mathematico* — * "Every natural diſquiſition "is brought to its proper iſſue, when a phyſical principle "terminates in a mathematical operation." The reverſe of this is the practice of Dr. *Keil:* he perceives that a thing will hold true in the *mathematics*, and then turns the world upſide down to make his *phyſics* agree with it. If that be the beſt philoſophy, which goes from phyſics to the mathematics; that muſt needs be the worſt, which goes headlong to the mathematics before it is ready for them, and canonizes a blunder by a demonſtration. So that Dr. *Keil* was rather too ſevere in cenſuring ſo unmercifully, and laying ſuch an heap of hard names upon his adverſaries, "whoſe "errors," he ſays "ſpring from hence, that men ignorant "of geometry will preſume to philoſophize, and give the "cauſes of natural things." For be it ever ſo true, that ſome philoſophers have not been geometricians; he hath ſhewn it to be equally true, that every geometrician is not a philoſopher.

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* Nov. Org. L. II.

I DO not ſay this to diſcourage the ſtudy of the mathematics: and if I had ſuch a deſign, my influence is too ſmall to be attended with any bad conſequences. However, I am far from deſigning any ſuch thing; but on the contrary am glad I know the value of mathematical learning, and would recommend the practical part of it to the ſtudy of every perſon who does not want leiſure, has no natural indiſpoſition for it, and is willing to make a progreſs in natural philoſophy; which, ſo far as it hath motion and quantity for its objects, cannot be rightly underſtood without a moderate degree of ſkill in the mathematics. If this ſtudy ſhould become more faſhionable among thoſe who are already learned in other reſpects, it might deliver us from the bondage of ſome tyrannical prejudices, which at preſent do very much obſtruct the advancement of natural knowlege. Electricity, which has given to this age an advantage over all that went before it, and ſhould have opened to us a new world of philoſophy, has left us juſt where it found us; and the curioſity of the publick with regard to that article hath nearly ſubſided, while the treaſures of nature are ſtill lockt up under the magic of *attraction* and a *vacuum.* And here we are like to remain; unleſs the efforts of ſome future philoſopher, more ſkilful and fortunate than I am like to be, ſhall rouſe the learned from their lethargic admiration of a few hard words, dreſſed up with geometrical lines and *algebra.*

ALL I wiſh for therefore is this, that our young gentlemen (for as to thoſe who are far advanced in age and opinion, though I reverence their characters, and am glad to take the benefit of their labours, it is too late to drive them upon any freſh inquiry) that our young gentlemen, I ſay, whoſe minds are diſengaged from ſyſtematical views, would avoid all implicit obedience to names and characters, ſo far as they can do it without any offence to good manners, and bend their attention to ſuch experiments as relate to a *material agency* in nature; which kind of experiments have neither been ſought after, nor examined into, as they ought to have been: and would likewiſe add to their other learning, a competent degree of ſkill in practical geometry and arithmetic. For it is the misfortune of theſe times in particular, that thoſe who are ignorant of the mathematics, are apt to think they have nothing to depend upon in phyſics, but the *authority* of the eminent geometricians; whoſe reports, however ſanguine, premature, and accommodated to their own fancies, they are obliged to receive juſt as they happen to be delivered: and while they are not aware how much may really be done by the mathematics, and what great aſſiſtance they will give in the proper place, are drawn in to allow them much more than their ſhare. On the other hand a mathematical ſcholar, whoſe judgment hath not been infected, doth know very well, that geometry can as ſoon *create* a ſyſtem of politics, as a ſyſtem of phyſics. He knows, that in every phyſical operation, he muſt have *phyſical data* to begin with; and that if he is wrong *there*, all the geometrical ſkill upon earth will never ſet him right; but rather lead himſelf and others into the danger of perpetuating the miſtake, by calling the work a *demonſtration.*

END OF THE FIRST BOOK.

BOOK II.

Attraction and gravity conſidered at large.

CHAP. I.

Attraction *inquired into from the writings of Sir* Iſaac Newton *and the moſt eminent of his followers.*

IN the former part of this treatiſe, I have made it appear, that the only rational and intelligible philoſophy is that which attributes all motion to the action of matter upon matter; or, which is the ſame thing, that maintains an agency of material and ſecondary cauſes, under the direction of God, the moral governor of the world, and the ſupreme cauſe of all things.

To ſuch a philoſophy as this, I have attempted to clear the way by removing all the principal objections of our modern learned men: and if the ſuppoſed evidence for a vacuum, depending upon the famous theory of reſiſtances, which gained ſo much credit with Dr. *Cotes*, and many others, as to be unhappily miſtaken for a *demonſtration*; if this, I ſay, has been obviated to the ſatisfaction of the learned reader, what remains to be done will rather be a work of eaſe and amuſement, than of difficult and doubtful diſputation.

For if the notion of a *vacuum* be unſupported, and falſe in itſelf, nothing that is advanced in the mathematical philoſophy, relating to *phyſical cauſes*, can poſſibly be right. Where that philoſophy has miſtaken or miſrepreſented the nature of theſe cauſes, it will be found inconſiſtent either with itſelf or with nature, and moſt probably with both: ſo that to detect the falſehood of it, we ſhall have nothing to do, but to compare it with itſelf, and with thoſe notions of the natural world, with which our ſenſes and experience will furniſh us. In this diſquiſition, we ſhall have in review before us, a great variety of uſeful and curious experiments, which cannot fail of giving ſome entertainment, to a mind that hath beſtowed any of its attention upon ſuch ſubjects.

As my concern at preſent is barely with *phyſical cauſes*, no reader can be ſo abſurd as to ſuſpect, that I am aiming at the demolition of all that is now called by the name of *natural philoſophy*, without doing me a manifeſt injuſtice, and betraying his own want of knowlege. The doctrine of *unmechanical cauſes*, though the forwardneſs and indiſcretion of ſome adventurers may have loaded it with a much greater weight than it is able to bear, does yet make but an inconſiderable part of the eſtabliſhed philoſophy; and if it ſhould hereafter give place to ſome more natural account of things, the remaining parts will always retain their preſent value. Such a work as that of profeſſor S' *Graveſande* will deſerve the admiration of the ingenious, ſo long as the world laſts; and that man muſt have but an indifferent reliſh for the ſciences, who is not greatly delighted with the diſcoveries and improvements he may there meet with, in *mechanics*, *optics*, and *aſtronomy*. I ſpeak this in much ſincerity: and it is intended to obviate any prejudices that might be raiſed againſt my deſign, either wilfully or by miſtake. To give offence is no part of my deſign; and I am unwilling, that any well-deſigning perſon ſhould think me to be poſſeſſed by a ſpirit of detraction, while I am conſcious to myſelf it is far from me, and that I write upon much higher motives. I am encouraged therefore to hope for the attention at leaſt, if not the favour, of all candid men and lovers of phyſical truth, while I enquire into the ſenſe and merit of thoſe *cauſes*, by which the author of nature is now ſuppoſed to direct the natural world.

FIRST then let us enquire, what kind of force or agency Sir *Iſaac Newton* and his followers would have us underſtand by the terms *attraction* and *repulſion*.

THAT *attraction* hath been called in for the explication of natural appearances, both great and ſmall, every perſon muſt know, who has either heard or read any courſe of phyſical lectures delivered in engliſh within this laſt century: it is looked upon as a principle, not to be approached without a degree of reverence, becauſe the great Sir *Iſaac Newton* thought proper to make uſe of it: but if the word ſhould have no fixed meaning, and ſhould itſelf want an explication, it will explain nothing at all; it will be a word without an *idea*; and if we apply it to any particular caſe, we ſhall explain, as the phraſe is, *ignotum per ignotius* "a thing "*unknown* by another that is *leſs known*." The word, if ſtrictly taken, ſignifies a *drawing* or *pulling* of one body toward another: but as every ſcience hath a liberty of adopting its own terms, provided it adds ſuch a definition as will keep them clear of ambiguity, I ſhall ſpend no conjectures upon it, but try if I can ſettle the three following queſtions, upon the beſt authority that is to be had — firſt, *where* attraction is ſeated? for example, whether it be in the earth, or in the ſtone that falls down to it, or in both, or in neither, but in ſome ſubſtance exterior to both? ſecondly, whether it is to be underſtood as a *cauſe*, or as an *effect?* and thirdly, whether it be a *material* force, or an *immaterial* one? under which heads, all that need be ſaid upon the ſubject may eaſily be reduced.

The principal ſpecies of attraction, being that of *gravity*, is deſcribed by Sir *Iſaac Newton* in his 5th definition as a *centripetal force*, whereby bodies are *drawn*, *impelled*, or *tend in any manner* toward a center: which definition is ſo far from giving any meaning to the word, that it rather ſeems to guard it, as it were, from having any meaning at all; there being a mixture of terms here, oppoſite in ſenſe to one another, ſuch as *attraction* and *impulſe.* To ſay a body is *attracted* or *pulled*, is to place the power in that point, to which the body is tending: to ſay it is *impelled* or *driven*, is to place the power *behind* it: but to ſay *both*, is to introduce two oppoſite forces, deſtructive of each other; which, in effect, is to ſay *nothing*. This definition therefore, as it now ſtands, will give us ſo little help, that we muſt divide it into two parts; that is, we muſt diſtinguiſh *attraction* from *impulſe*, as things diametrically oppoſite, and ſee to which of theſe two Sir *Iſaac* and his followers have inclined.

If we look forward in the *principia*, we ſhall accordingly find, that *attraction* is the favourite term upon which all the learned author's reaſonings turn; and that he ſuppoſes it to be a power ſeated *in the moved bodies themſelves*, and in every *ſingle particle* of which they are compoſed. What elſe can we underſtand by * *corpora trahentia*, "drawing bodies;" and, *corpora ſe invicem trahentia*, "*bodies that mutually draw each other*," and † *ſphæræ ex materiâ attrac-*

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* Lib. I. Sect. 11.

† Ibid. Prop. 72.

tivâ conſtantes, "ſpheres compoſed of *attractive matter?*" How again are we to eſtimate, as he directs, the attractions of bodies "by aſſigning to each of their particles their *own* "*proper powers* [*]," unleſs the *power*, by whatever *name* he pleaſes to call it, be as truly ſeated in the particles themſelves, as the force of reſiſtance, or *vis inertiæ* is ſuppoſed to be? And if the learned author of this doctrine had not really ſuppoſed the ſolid matter of the parts themſelves to be endued with an active power, or principle of motion, he would not ſurely have taken ſo much pains to prove, that this power cannot be owing to any *æther*, or other matter, external to the moved body. For he ſets it down as the reſult of his reaſonings and experiments, that no ſpecies of matter can be *void of gravity* [†]; whence the concluſion is obvious enough, that no matter can act as the cauſe of gravity; unleſs the *effect* of gravity in ſome bodies, can be the *cauſe* of it in others, which is abſurd. It remains then, that the gravity of all bodies is owing to a *quality* [‡] reſiding in the bodies themſelves; to which quality he gives the name of *attraction*. How much truth there is in the grounds of this concluſion, we ſhall ſee hereafter; when gravity, as an univerſal property of matter, is compared with experiment.

THERE are in the celebrated works of Sir *Iſaac*, ſo many paſſages ſeemingly inconſiſtent with the doctrine abovementioned, and eſpecially that portentous paragraph with which he has concluded his *principia*, that I would proceed with all due caution, and not venture to fix ſuch an opinion upon him, without taking ſome farther counſel, and enquiring *how*, and *in what ſenſe*, this doctrine has been received in the judgment of others, who ſubſcribed to his opinions, and underſtood them throughly.

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[*] Aſſignando ſingulis eorum particulis *vires proprias*. Lib, I. P. 69. Schol.

[†] Lib. 3. P. 6. Cor. 2.

[‡] Hæc eſt *qualitas* omnium &c. *Ibid.*

Dr. *J. Keil*, who beſtowed much pains in drawing out this principle of attraction into a theory, has the following aſſertion — *Materiæ ineſſe vim attractricem, confirmat experientia*; "experience teaches us, that there is *in matter* an "attractive power. This he calls — *materiæ vis ſuperaddita*, "a force *ſuperadded* to matter;" and again, *ineſt materiæ potentia, quâ ſingulæ, ex quibus conſtat, particulæ ſe invicem attrahunt* — "There is a *power in matter* by which all "its particles mutually attract one another *." So that in the conſtitution of all bodies, there is a compoſition of *matter* and *power*; and if their parts are found, either to adhere, or tend toward each other, we muſt aſcribe it to a virtue in the parts themſelves. If an heavy body falls to the earth, it is occaſioned by a *vis* or *potentia* ſuperadded to the matter of them both: than which nothing can be more expreſs to the point; and it ſhews us, to a demonſtration, how *attraction* was underſtood by Dr. *Keil.*

Dr. *Friend*, who endeavoured to ſolve the operations of *chemiſtry* by this principle, and was engaged in a controverſy about it with ſome foreign writers, was of the ſame mind with Dr. *Keil*. In the defence of his lectures, he calls it — *principium attrahens, quod omni materiæ ineſt* — "a drawing "principle that reſides *in all matter*." And again he aſſerts — *Ineſſe immutabilem quibuſcunque corporibus vim*, quâ *itidem in ſeſe mutuò ferantur* — "that bodies are carried mu"tually toward each other *by* an immutable *power within* "*themſelves* †.

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* Philoſ. Tranſ. No. 315.

† *Ibid.* No. 331.

Dr. *Clarke* in his notes on *Rohault* informs us, that “all thoſe bodies will aſcend in water, which are leſs *at-* “*tracted by the gravity of the earth* than water itſelf[*].” Whence it appears, that according to his notion of the affair, *attraction* is a quality reſiding in the matter of the earth itſelf; it being the *gravitas telluris*, to which the effect is imputed.

To theſe authorities, I may add that of the ingenious Mr. *Rowning*; who, ſpeaking of the attraction of gravitation, obſerves in very plain terms, that “the *action of the* “*earth* upon bodies is exactly in proportion to the matter “they contain[†].”

But above all, the opinion of Dr. *Cotes* is to be regarded; and it is more to my purpoſe than any of the former. “We are to believe, ſays he, that the *action of the earth* is “compoſed of the joint *actions* of all its *parts*; and there- “fore, that all terreſtrial bodies ought to *attract* one ano- “ther with abſolute forces, which are in a direct ratio of “the *drawing matter*[‡].”

All theſe authors then (and I might have added many others) who have followed the Newtonian hypotheſis, declare with one voice, that when a terreſtrial body is ſo acted upon as to deſcend to the earth, the *drawing matter* of the earth itſelf is the *agent*; and it *acts* by a *power ſuperadded* to it, which power they call *attraction.* All the other kinds of attraction, ſuch as that of *magnetiſm*, *coheſion*, *electricity*, and *repulſion* the antagoniſt of them all, are to be underſtood in the ſame way: but I forbear to weary the reader's patience with any particular proofs of it. This, I remember very well, is the ſenſe in which I myſelf, in common with other young men, underſtood the doctrine of attraction, when I was firſt initiated into theſe myſteries of natural philoſophy: it is the ſenſe in which I thought Sir *Iſaac* did originally deſire to be taken; and in which, I am confident he is taken to this day, by very many readers. I am now perfectly eaſy about it, being in the company of thoſe writers, whoſe learning and candour with regard to their author have never yet been diſputed.

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[*] Quæ *telluris gravitate* minus ſunt *attracta.* P. I. ch. 22. §. 15.

[†] Vol. I. p. 15.

[‡] *Actio* itaque telluris ex conjunctis partium *actionibus* conflari cenſenda erit; atque adeo corpora omnia terreſtria ſe mutuo *trahere* oportet viribus abſolutis, quæ ſint in ratione *materiæ trahentis.* See his Pref. to Sir *Iſ. Principia.* p. 3.

CHAP. II.

An attempt to ſettle the queſtion, whether attraction *is the* cauſe *or the* effect.

IT will now appear very ſtrange to aſk whether attraction be a *cauſe* or an *effect*; *action*, *force*, *power* &c. having all been aſcribed to it: but this enquiry will anſwer a very good purpoſe, and ſerve abundantly to convince the unprejudiced, that they, who brought this principle into faſhion, did never yet know what to make of it.

MR. *Leibnitz*, and many other learned mathematicians, were for exploding *attraction* at its firſt appearance: they even ridiculed it as unphiloſophical, unintelligible, an occult quality, and a miracle; and abſolutely denied its very exiſtence. Obſerve therefore what a reply Dr. *Clarke* made upon the occaſion — "It is very unreaſonable to call attraction

"traction a miracle and an unphiloſophical term, after it "has been ſo often diſtinctly declared, that by that term, we "do not mean to expreſs *the cauſe of bodies tending toward* "*each other*; but barely the *effect* of this cauſe, or the *phœnomenon itſelf* diſcovered by experience, whatever be or be "not the cauſe of it. Gravitation or attraction *in this ſenſe* "(he adds) is an actual phœnomenon in nature*." And again: "philoſophers therefore may ſearch after and diſco"ver that cauſe if they can, be it mechanical or not me"chanical: but if they cannot diſcover the cauſe, is there"fore the *effect itſelf*, the *phœnomenon*, or the *matter of* "*fact diſcovered by experience*, (which is all that is meant by "the words *attraction* and *gravitation)* ever the leſs true †?" Mr. *Leibnitz* objected to *attraction*, as to a *cauſe* occult and unphiloſophical: Dr. *Clarke* anſwers him, by denying it to be any *cauſe* at all; for that it means nothing more than the bare *effect*, or *phœnomenon* of a *tendency* in one parcel of matter toward another. And if this were all, who could take any offence at it? for that there is ſuch a tendency, experience will indeed convince us; and there are few aſtronomers, who will not allow of it, even in the heavenly bodies themſelves. But then the authority, to which this author has referred us, is no way to be reconciled with his account. The words of Sir *Iſaac* are theſe "I uſe the word "attraction, only in general, to ſignify the *force by which* "bodies *tend* toward each other ‡." Dr. *Clarke* aſſures us very poſitively, and deſires he may not be miſunderſtood, that when bodies are ſaid to be *attracted* or *gravitate*, nothing farther is meant, but that they are found by experience to *tend:* whereas Sir *Iſaac* affirms, in the very words to which he has referred us, that attraction expreſſes that

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* P. 355.

† P. 367.

‡ Opt. Q. 23

force in general *by which* they tend; and theſe two are as diſtinct as a cauſe and an effect can be; juſt as different, as is the *tendency* of a bullet toward the mark, from the *force* of the gunpowder, *by which* it is ſent from the piece. And the following words are ſufficient to prove, that notwithſtanding what Dr. *Clarke* might think it convenient to ſay to Mr. *Leibnitz*, Sir *Iſaac* did not publiſh his attraction of gravity to the world under the notion of an effect — "It is "enough, ſays he, that *gravity* really exiſts, and *acts* ac-"cording to the laws we have laid down*;" which an *effect*, I think, can never be ſaid to do, without a childiſh abuſe of language.

LET us next examine the opinion of Dr. *Cotes*, who thus appeals to his adverſaries, in behalf of the *Newtonian* gravity — "Would you call gravity an *occult cauſe*, becauſe "the cauſe of gravity is occult, or not yet found out?" No, certainly I would not: for if its *cauſe* remains yet to be diſcovered, I would have obſerved the caution given by Dr. *Clarke*, and have called it an *effect*. For if gravity be a phyſical cauſe, we have already gained our purpoſe, and the ſcience of phyſics does not require us to look for another. If it be a cauſe of ſo myſterious a nature, that no phyſical account can be given of it, it muſt be claſſed among thoſe occult qualities, which the ſcholaſtic philoſophers affirmed to have a real exiſtence, though they were unable to give any farther account of them. We have the authority of Dr. *Cotes* however, that gravity is a *cauſe*, which was juſt now affirmed to mean nothing but an *effect*; and the adverſaries of this philoſophy were charged with the *unreaſonableneſs* of a contrary ſuppoſition. From what this author hath written, it appears he never ſuſpected gravity to be any thing but a cauſe, even the moſt ſimple of cauſes, beyond which human knowlege cannot poſſibly penetrate — *ubi ad cauſam ſimpliciſſimam perveneris*, (ſuch as he ſuppoſes gravity to be) *jam non licebit ulterius progredi* [*]. He thinks there is a concatenation of phyſical cauſes in the world, ſome compounded, others ſimple and primary; but *gravity* he places among the *cauſas ſimpliciſſimas*, and *cauſas per phœnomena comprobatas*; which latter expreſſion ſets him in a direct oppoſition to Dr. *Clarke*; with whom attraction and gravity mean nothing but the bare effect or phœnomenon itſelf: here, it is the *cauſe* proved *by the phœnomenon.* And it ſhould be remembered for the juſtification of Dr. *Cotes*, that he wrote in the year 1713, Dr. *Clarke* in 1717.

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* Satis eſt quod *gravitas* revera exiſtat, & *agat* ſecundum leges a nobis expoſitas. *Princip.* p. ult.

DR. *Deſaguliers* will inform us, that "*attraction* and *re*-"*pulſion* ſeem to be ſettled by the great creator as firſt prin-"ciples in nature, that is, as the firſt of *ſecond cauſes*; ſo "that we are not ſollicitous about *their* cauſes, but think it "enough to deduce other things from them [†]." This confirms the reflexion I made a while ago; that attraction is a cauſe, of which no account can be given; and that it ſerves to keep us under the ſame ignorance with the occult qualities of the ſchools. It was for this reaſon only, that the learned men of the laſt age remonſtrated againſt it with ſo much earneſtneſs; and Sir *Iſaac*, in order to remove the offence it had given, took the matter a ſecond time into conſideration. When he viewed it in a phyſical light, he concluded from ſome particular experiments, "that there are "*agents in nature* able to *make* the particles of bodies ſtick "together by very ſtrong attractions; and that it is the bu-

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[*] *Princip.* Pref. p. 9.

[†] Phil. Tranſact. No. 454.

"ſineſs of experimental philoſophy to find them out;" that is, to find out thoſe *agents of nature*, which act as the immediate *cauſes* of this *attraction.* By which remarkable conceſſion, Sir *Iſaac* himſelf, who elſewhere makes attraction a *force*, and gravity an *active principle*[*], has reduced them both to *effects*; encouraging us, at the ſame time, to enquire experimentally after thoſe agents of nature, by which theſe effects are brought about; while *Deſaguliers* his diſciple lays down attraction itſelf as the *firſt of ſecond cauſes*; and Dr. *Cotes* aſſures us, that if we get ſo far, *jam non licebit ulteriùs progredi.*

IF we aſk the opinion of Dr. *Friend*, he will tell us, gravity is an effect, and attraction is the cauſe of it. "This "*attraction*" (which he had juſt before called the *force of gravity)* "they may, if they pleaſe, call an occult quality; "and I believe it will always be occult:" yet, in another part of the ſame diſcourſe, he ſays "In explaining this gra-"vity, which is evident to ſenſe, *Newton* hath far exceeded "all other philoſophers; having demonſtrated it to ariſe "from an *attractive force*, which diſperſes itſelf far and "wide through all matter[†]." From which paſſages, we may learn theſe three things: firſt, that gravity and attraction are the ſame thing[‡], becauſe the author, ſpeaking of the *vis gravitatis*, calls it — *hæc attractio.* Secondly, that attraction is an *occult quality*, and always like to remain ſo. Thirdly, that *gravity* is *beſt explained by attraction*; though, by his firſt ſuppoſition, they are the ſame thing; and then gravity is beſt *explained by itſelf:* by the ſecond, attraction is allowed to be an occult quality, and he believes it will always remain ſo. Which doctrine comes out juſt as it ſhould do; for to explain any thing by an occult quality, is to explain it by itſelf: and in this abſurdity, the *cauſes* propoſed by the mathematical philoſophy will all be found to terminate.

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[*] Opt. p. 376.

[†] Attractionem hanc (ſcil. *vim gravitatis)* ſi ita lubet qualitatem occultam nuncupent, & erit, credo, ſemper occulta. — In hâc quidem gravitate *explicandâ*, quam ſenſu percipimus, longiſſime omnium proceſſit *Newtonus*; eam quippe *a vi attractrice* quæ per omnem materiam ſe undequaque diſſeminat *oriri* commonſtrat. Ubi ſuprá.

[‡] See the paſſage quoted from Dr. *Clarke* at p. 62, 63.

How oppoſite to thoſe of this laſt-named author, were the ſentiments of the celebrated *M. Maupertuis*; who thus apologizes to the French academy in behalf of the Newtonian attraction — “Many people, ſays he, have been diſguſted “by the word *attraction*, expecting to ſee the doctrine of “occult qualities revived again in natural philoſophy: but “in juſtice to Sir *Iſaac Newton*, it ſhould be remembered, “he has never conſidered attraction as an explanation of the “gravity of bodies toward each other: he has frequently “warned us, that he employs this term, not to ſignify a “*cauſe*, but only an effect[*].” Therefore in the judgment of this learned man, whoſoever recommends attraction to us as a phyſical *cauſe*, or an *explanation* of effects, revives the doctrine of occult qualities.

LASTLY, let us hear the opinion of Mr. *Rowning*, a writer who has done much ſervice to the publick, by giving us a regular treatiſe upon natural philoſophy in all its branches. But alaſs! we ſhall find him to have fallen into the ſame inconſiſtency with the other writers who went before him; which I would impute wholly to the perplexed condition of the ſubject, and not to any intention of deceiving in the author. "It is to be obſerved (ſays he) that when we uſe "the terms *attraction* or *gravitation*, we do not thereby de-"termine the phyſical cauſe of it, as if it proceeded from "ſome ſuppoſed occult quality in bodies; but only uſe thoſe "terms to ſignify an effect, the cauſe of which lies out of "the reach of our philoſophy. We may ſay that the earth "attracts heavy bodies, though at the ſame time we are "wholly ignorant whether this is effected by ſome power "actually exiſting in the earth or in the bodies, or external "to both.*"

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[*] Le mot d'attraction a effarouché les eſprits; pluſieurs ont craint de voir renaître dans la philoſophie la doctrine des qualites occultes; mais c'eſt une juſtice qu'on doit rendre a M. Newton, il n'a jamais regardé l'attraction comme une explication de la peſanteur des corps les uns vers les autres, il a ſouvent averti qu'il n'employoit ce terme que pour deſigner un fait, & non point une cauſe. Vid. *Aſtron. Phyſ.* par Mr. *de Gamaches*. p. 348.

Now although *attraction* be an unhappy word by which to expreſs an effect, yet if Mr. *Rowning* were conſiſtent with himſelf in this matter, and carried the thing no farther, it would be well enough: but the contrary will ſoon appear, from a few ſhort remarks upon this paſſage. *When we uſe the terms attraction or gravitation, we do not thereby determine the phyſical cauſe of it.* Of what? of attraction? *that* is not the thing required. We only deſire to know, whether attraction really exiſts in nature, as a *force* or active principle; and whether we are to underſtand it as a *cauſe* of natural effects? or whether it be barely the *phænomenon* of a tendency or motion, the cauſe of which is yet to be ſought after? It can never be expected, that the word *attraction* ſhould be expreſſive of its *own cauſe*; eſpecially if it be one of Dr. *Cotes*'s moſt *ſimple of cauſes, and ſuch as hath no dependence upon any other* †. The complaint is this; that attraction is propoſed to us as an effect; but if once admitted, it is thenceforward forced upon us as a *cauſe*; as a ſolution of every difficulty; while attraction itſelf is the greateſt difficulty of all. That it is applied as a cauſe by Mr. *Rowning*, I ſhall ſhew hereafter: that it is not to be underſtood as an effect, may be proved from his own definition of it. “Matter, ſays he, has alſo certain *powers* or *active* “*principles*, known by the names of *attraction* and *repul*“*ſion*, impreſſed upon it by the author of its being, for the “better *performance of the offices* for which it was deſign“ed †.” If attraction, as the author ſays elſewhere, be a term uſed only to ſignify an *effect*; how comes it to be here deſcribed, as a *power* or *active principle*; which are appellations utterly repugnant to the notion of a natural *effect*? can an effect *perform offices*, and be *active* toward the production of an effect? that ſurely muſt be the work of an agent or phyſical cauſe; and attraction muſt undoubtedly be taken for ſuch, if it can be proved to perform any phyſical offices. But, ſays Mr. *Rowning* “we are wholly ignorant “whether this is effected by ſome power, actually exiſting “in the earth, or in the bodies, or external to both.” And here he ſeems to have forgotten his own definition of attrac“tion; it being a *power impreſſed upon* matter; others ſay, it is *in* the matter, and that the point has been *demonſtrated*. But if after all this, we are wholly ignorant, whether it be within the matter, or without it, the obſcurity of the whole becomes invincible, and attraction can ſerve only to raiſe a duſt.

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* Vol. I. p. 17.

† Dantur certè primariæ corporum affectiones, quæ *quoniam ſunt primariæ*, non pendent ab aliis. *Ubi ſup.* a piece of reaſoning altogether ſcholaſtic.

TRUTH, it is ſaid, is not to be ſpoken at all times: but ſometimes one cannot proceed a ſtep without ſpeaking it, and that is my caſe at preſent. Attraction then, as Mr. *Rowning* and others have defined it, is an *occult quality*, an ισχυς, δυναμις, *affectio*, *facultas naturalis*, *vis inſita*, or any thing in that way. But to avoid the imputation of this, ſome after-thought is generally added, to take off, as it were, and qualify the ſenſe of their definition; which renders the caſe ſtill worſe. For if you aſſert poſitively, that matter has an active principle or power *in it*; and afterwards confeſs, you cannot tell *what* it is, *where* it is, nor the *manner* in which it produces any ſingle effect, or whether it produces any effect at all; then, if ever there was an occult quality maintained in the ſchools, attraction muſt be ſuch a quality; and Dr. *Friend* has allowed us the liberty of ſo underſtanding it.

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† *Ibid.* p. 12.

But I promiſed to ſhew, that although Mr. *Rowning* be in doubt what to call his attraction, yet in practice he applies it, not as the *phœnomenon itſelf*, but as the *cauſe* of it, and for the purpoſes of *explanation*. "The riſe of the water in "capillary tubes (ſays he) is manifeſtly owing to the attrac-"tion of thoſe particles of the glaſs, which lie in the inner "ſurface of the tube immediately above the water *. In his account of which experiment, we have two things clearly diſtinguiſhable one from the other: the *riſe of the water in the tube*, and the *attraction of the particles that lie in the inner ſurface of the glaſs*. The former is the effect manifeſt to ſenſe; the latter is the cauſe to which it is manifeſtly owing. If it ſhould be ſuſpected that I miſunderſtand him; then I ſay, attraction muſt be either the cauſe or the effect: if it be the effect, then to affirm that the riſe of the water is manifeſtly owing to attraction, is but to ſay in other words, that *the effect is manifeſtly owing to the effect*. If it be taken for the phyſical cauſe, and I ſhould deny the reality of its exiſtence, how would you prove it? you will refer me perhaps to the phœnomenon, for that is the common way of reaſoning, and tell me I cannot help ſeeing it. But *attraction* is not the phœnomenon; it is Mr. *Rowning's explanation* of it. The phœnomenon, evident to ſenſe, is only the riſing of the water; the *attraction of the glaſs*, not evident either to ſenſe or reaſon, is ſet down as the cauſe to which it is manifeſtly owing: and this cauſe, as the author hath affirmed in another place, is a term uſed only to ſignify an effect.

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* V. I. p. 13.

THE nature of attraction is ſuch, that we have ſucceeded but very indifferently in this part of our enquiry, as I could plainly foreſee we ſhould. The ſubject is involved in an obſcurity, either ſtudied or unavoidable; and in all the paſſages I have been able to collect and compare, there is ſomething that appears like a ſlight of hand, whereby the *effect* is ſhifted into the place of the *cauſe*. As I am unable to draw any doctrine from the whole with preciſion, it will be beſt to introduce the authors giving their verdicts in their own words, and leave the reader to his own judgment.

SIR *Iſaac Newton*. "Gravity exiſts and *acts*."

DR. *Friend*. "In *explaining* gravity, *Newton* has de-" monſtrated it to ariſe from an *attractive force*."

M. Maupertuis. "It ſhould be remembered in juſtice to Sir *Iſaac Newton*, he has never conſidered *attraction* as an *explanation of gravity*. He conſiders it not as a *cauſe*, but as an *effect*."

DR. *Cotes*. "Gravity is the moſt ſimple of *cauſes*."

DR. *Clarke*. "It has often been diſtinctly declared, that " by the term *attraction*, we do not mean to expreſs the " *cauſe* of bodies tending toward each other, but barely the " *effect*, the *effect itſelf*, the *phænomenon*, or *matter of fact*."

DR. *Deſaguliers*. "*Attraction* ſeems to be ſettled by the " great creator as the *firſt of ſecond cauſes*."

MR. *Rowning.* "When we uſe the term *attraction,* we "do not determine the phyſical cauſe of it, but uſe it to "ſignify an *effect:* nevertheleſs, to attraction effects are *ma*"*nifeſtly owing.*"

SIR *Iſaac Newton.* "There are *agents in nature* able to "make the particles of bodies ſtick together by very ſtrong "*attractions,* and it is the buſineſs of experimental philoſo"phy to *find them out.*"

DR. *Deſaguliers.* "We are not ſollicitous about the *cauſe* "*of attraction.*"

DR. *Friend.* "I believe *attraction* will always be *oc*"*cult.*"

THIS is the reſult of my enquiry: and if any perſon ſhould be ſo inclined, he is welcome to lay all the blame upon my want of underſtanding. But if theſe learned men, who are all vindicating the ſelf ſame principles of philoſophy, had no clear ideas of what they affirmed, and could not underſtand *one another*; it is no wonder, if the world ſhould be at ſome loſs to underſtand *them.*

CHAP. III.

Attraction, a material *force in the judgment of ſome authors*; *an* immaterial *force in the judgment of others*; *and ſometimes both* one *and the* other *in the judgment of the* ſame *author*.

WE have yet a third queſtion to ſettle, *viz.* whether *attraction* be a *material* force, or an *immaterial* one? and here we ſhall have the ſame ſcene as before; this point being left equally undetermined with the former. Indeed nothing can be more evident, than that Sir *Iſaac Newton*, great as he was, hath offered to the world his thoughts on a queſtion of much importance, and taken *both ſides* of it. It is diſagreeable to me to ſay this; but it muſt be ſaid, becauſe it is certainly true; and I cannot go forward without ſaying it. This, as we ſhall find, has divided his followers; and their diſputes with each other in regard to firſt-principles and fundamentals, have as great an appearance of fallibility and uncertainty, as other diſputes uſed to have, before the ſcience of natural philoſophy was enriched with demonſtration: of which I ſhall exhibit a notable inſtance, from the writings of the celebrated Mr. *Maclaurin*, and his antagoniſt, the author of an *enquiry into the nature of the human ſoul.*

BUT firſt let us attend to Sir *Iſaac* himſelf. There is a paſſage in his *optics*, wherein he allows, that what he imputes to *attraction* may be performed by *impulſe*[*]. Dr. *Clarke* in his notes on *Rohault* cites this paſſage; and left we ſhould take the impulſe here ſpoken of, to be that of ſome intervening *matter*; he inſerts by way of comment —*non utique corporeo*—[*] declaring, that this *impulſe* is *not corporeal*; or, in other words, that it is not the impulſe of any material agent. We have the ſame ſentiment from him upon another occaſion —"It is now allowed on all hands, "that gravity does not depend on the action of the air or "*æther*, but is a primigenial, innate, and unchangeable af"fection of all matter [†]." This is in anſwer to the great Dr. *Wallis*, who was of another mind. He ſuſpected that gravity, though uſually taken for a primary quality, might be owing to the *percuſſion* of ſome impelling matter, and propoſed a ſhrewd caſe to countenance his opinion: but I forbear to ſay any thing farther of it in this place.

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[*] P. 351.

Mr. *Rowning*, who has laid down the received philoſophy with as much diligence and fidelity as any man, hath affirmed nothing ſo expreſſly, as that "theſe *diſpoſitions* in "bodies (ſuch he calls gravitation, attraction &c.) are not "the reſult of any mechanical cauſe whatever; that is, ſuch "as may ariſe from the action of any material ſubſtance [‡]." And he has treated his mathematical readers with a demonſtration, proving the impoſſibility of it. Profeſſor S'*Graveſande*, from whoſe great abilities we might have expected ſomething more ſatisfactory, unhappily fell into the ſame way of reaſoning; and gave a geometrical demonſtration (as he thought) that the ſpherical figure of a drop of water cannot be occaſioned by the *equal preſſure* of any fluid medium.

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[*] P. 51.

[†] Verum cum jam in confeſſo ſit, gravitatem non ab aere *æthereve* pendere, ſed eſſe primigeniam, connatam, immutabilemque materiæ *affectionem* &c. p. 61.

[‡] Pref. p. 6. Dr. *Cotes* hath affirmed the ſame, in his preface to the ſecond edition of the *Principia*—*Gravitas*—*ex aliis corporum affectionibus atque adeo ex cauſis* mechanicis *originem* non *habet*. p. 9.

More authorities to the ſame purpoſe might eaſily be produced; but this doctrine hath been ſo largely and confidently maintained by ſo many writers, that I muſt have the aſſent of the learned, if I ſet it down as a doctrine of Sir *Iſaac Newton.*

BUT then, on the contrary, it is to be remembered, that this introducing of immaterial impulſes into the world of matter, firſt raiſed a clamour againſt his philoſophy, as tending to revive all thoſe occult qualities, which had been ſo happily baniſhed, but a while before, from all books of natural philoſophy. To obviate this, and to *ſhew*, as the author expreſſes himſelf, "that he did not take gravity for an "eſſential property of bodies," *he added a queſtion concerning its cauſe* *. This *cauſe* he ſuppoſes to be a *ſubtil ætherial medium* — *readily pervading all bodies* — *expanded through all the heavens* — *cauſing the* gravity *of thoſe great bodies* (the ſun, planets, comets &c.) *towards one another*, *and of their parts toward their bodies* — and ſuch as *may ſuffice to* impel *bodies from the denſer parts of the medium toward the rarer with all that power which we call gravity* †. This, I ſay, is propoſed as a *material cauſe.* For, is it not a *medium*, capable of *rarity* and *denſity*, ſubject to a kind of *vibrations* or pulſes? and an *immaterial medium* would be an *ens rationis*, a philoſophical ſpectre, a contradiction in terms.

HERE then, we have two different ſyſtems of philoſophy. According to the former of them, all the operations of nature are conducted by the means of *unmechanical* and *immaterial impulſes* in a *vacuum*; but according to the latter, they have as their immediate *cauſe*, an *æther* expanded through all the heavens: and he that ſhall take up either with the one or the other, or with the one againſt the other, will have Sir *Iſaac Newton* on his ſide. But whoever ſhall aſſume them *both* as true, will bring himſelf into great diſtreſs and difficulty.

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* Opt. Advert. II.

† See Opt. Q. 18. 19. 20. 21.

This was the fate of the ingenious Mr. *Maclaurin*, a learned and elegant writer, who undertook a formal defence of the *Newtonian* hypotheſis againſt all the objections that had been made to it; and was well qualified, if any man could be ſo, for the undertaking. He underſtood his ſubject perfectly; and was ſenſible he could never do juſtice to the *principia*, without baniſhing all material cauſes from the heavens. This he attempts to do, though it is frequently with ſome reſerve, in ſeveral parts of his treatiſe; particularly in the following words — "as for a more ſubtil medium than the air, no experiments nor obſervations ſhew, "that there is any here, or in the celeſtial ſpaces, from which "any ſenſible *reſiſtance* can ariſe [*]." Mr. *Maclaurin* was very well inclined to admit a material agency in ſubordination to the firſt cauſe [†]; but this falſe doctrine of *reſiſtance* tied up his hands; otherwiſe his work might have been all of a piece. As it ſtands now, the moſt valuable paſſages in it, are ſo many contradictions to all the reſt. After what he has ſaid above who would expect to hear him reflect upon "others, who while they overlook the intermediate *links* in "the *chain of cauſes*, and haſtily reſolve every principle into "the *immediate influence* of the firſt cauſe, impair the beauty "of nature, put an end to our enquiries into the *moſt ſublime parts of philoſophy*, and hurt thoſe very intereſts they "would promote [‡]." They do ſo moſt undoubtedly: but hath not the mathematical philoſophy this tendency? doth it not oblige us to deny, againſt reaſon and our better knowlege, that *any experiments or obſervations ſhew that there is a medium more ſubtil than air?* hath not Mr. *Maclaurin* himſelf denied it in theſe very words? And elſewhere in the moſt categorical terms, he hath aſſerted an abſolute *vacuum* — "Sir *Iſaac Newton*'s philoſophy (ſays he) has ſhewn, that "not only there may be, but that there *actually is a vacuum* — that matter appears to occupy but *a very ſmall* "*portion* of ſpace [*]." If this ſhould be true, what becomes of his *chain of cauſes?* for if there be no medium concerned as a ſecondary cauſe in the motion of the planets &c. it folfows unavoidably, that there muſt either be inherent and ſelf-moving *powers in matter*; or that the influence of the firſt cauſe, muſt be *immediate*; for there is nothing elſe remaining, and then Mr. *Maclaurin*'s chain will conſiſt but of one link. This is the opinion, which he thinks, muſt *put an end to our enquiries into the moſt ſublime parts of philoſophy.* And leſt it ſhould be ſuſpected, that Sir *Iſaac*'s method of philoſophizing has introduced *immaterial powers* and occult qualities, we are aſſured by this author, that "he "does never affirm or inſinuate that a body can *act upon* "*another at a diſtance*, but by the intervention of other bo- "dies [†]." But his zeal hath carried him a little beyond the truth: the thing he here denies, being much more than *inſinuated* in theſe words — "Have not the ſmall particles of bodies "certain *powers*, virtues, or forces, by which they "*act at a diſtance*, not only upon the rays of light — but "alſo upon one another, for producing a great part of the "phœnomena of nature? for it is well known that bodies "*act upon one another* by the *attractions* of gravity" &c [‡].

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[*] P. 294.

[†] This is very manifeſt from the 14th ſection of his laſt chapter.

[‡] P. 95.

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[*] P. 77.

[†] P. 109.

[‡] Opt. Q. 31.

Attraction, as a power acting *at a diſtance*, is here left in full poſſeſſion; not a ſyllable being inſerted, as I can find, concerning the *intervention of other bodies.* If this intervention were admitted, how would it agree with what Dr. *Clarke* has ſo frequently inculcated, throughout his notes on *Rohault*'s phyſics? He ſticks not to aſſert an *impulſus non utique corporeus*, and an *actio cauſæ cujuſdam immaterialis — per interjectum aliquod intervallum* &c. ſee p. 50. Beſides, the ſenſe of the whole paſſage, would be overthrown by Mr. *Maclaurin*'s ſuppoſition; for if other bodies intervene, then attraction will not be a power acting *at a diſtance*, but by a *communication* of bodies that are in contact. The author (Sir *Iſaac Newton*) does indeed inform us a while after, that he uſes this word to *ſignify only in general any force* * &c. but this does not alter the caſe: for let it be a force *in general*, yet it hath this *particularity* in it, that it *acts at a diſtance*, which is the nature of an *occult quality*, and is the very thing that has all along been objected to. And though Mr. *Maclaurin* hath taken great pains to get handſomely rid of this unintelligible power, yet is the exiſtence of ſuch a power abſolutely neceſſary upon his own principles. Sir *Iſaac*, he ſays, hath ſhewn, that there *actually is a vacuum*, and that the *parts of matter are actually divided and ſeparated from each other*: after which it would be ſtrange indeed, if they were to *act* otherwiſe than in this ſtate of *diviſion and ſeparation*, that is, *at a diſtance*. When he ſuppoſes other matter to *intervene*, till the action will conſiſt with mechaniſm, he apologizes for a *vacuum*, at the expence of the principle itſelf; which by this means is turned into a *plenum*, whether the author was aware of it or not.

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* Ibid.

How unſeaſonably therefore was it obſerved by Mr. *Maclaurin*, that "poſſibly ſome unſkilful men may have fan- "cied, that bodies might attract each other by ſome charm "or *unknown virtue*, without being impelled or *acted upon* "by other *bodies*[*];" for if this was not a fancy of Sir *Iſaac Newton* himſelf, in common with ſome of the moſt ſkilful of his followers, the plaineſt engliſh can have no meaning. I know very well, his writings contain many paſſages which ſeem to have a contrary meaning: and his diſciples find ſuch an advantage in this, that they have an anſwer ready upon all occaſions. For example, if you ſuppoſe the world to be ruled by a ſubordination of material inſtruments, in oppoſition to Sir *Iſaac*'s vacuum; then you are told, there is *no medium more ſubtil than air*; that the heavens are *void of all ſenſible matter*; and it is demonſtrated againſt you *geometrically*, that attraction *cannot ariſe from the action of any material ſubſtance whatſoever*. If you ſhould lay hold of this, and object to attraction as a principle *occult* and *unphiloſophical*, then it is only the *fancy of ſome unſkilful men*; and Sir *Iſaac Newton* has *plainly ſignified*, *that he thought that thoſe powers aroſe from the impulſes of a ſubtil ætherial medium that is diffuſed over the univerſe*[†]. Thus you are confuted either way; and your reaſoning is repreſented as *crafty*, *diſingenuous*, and *unworthy of a philoſopher*[‡].

By this artifice, Mr. *Maclaurin* would have quieted all our ſcruples; but ſeems to have miſcarried in the attempt, having been obliged to contradict his author *in terminis*; and I may add, *himſelf* alſo; as it hath been fully proved againſt him by Mr. *Baxter*, the author of an *appendix to an enquiry into the nature of the human ſoul.*

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[*] *Ubi ſup.*

[†] *Maclaurin*'s Phil. Diſc. p. 111.

[‡] See p. 110.

THERE are two different modes of philoſophy before us, both of which have Sir *Iſaac Newton* at the head of them. Mr. *Maclaurin*, by eſpouſing them *both*, fell upon various contradictions. Mr. *B* — is more cautious; and hath written with ſome warmth on one ſide, againſt Mr. *Maclaurin* who is on both ſides. Where the latter hath really laid himſelf open, he makes good uſe of the opportunity; without conſidering where, and upon *whom*, his cenſures will at laſt be fixed [*]. He is clearly of opinion, that the material cauſes, occaſionally introduced by his adverſary, are utterly inconſiſtent with what is eſtabliſhed in the *principia*; and is therefore a declared enemy to all *ſubtil matter*, even to that *æther* of Sir *Iſaac*, for which Mr. *Maclaurin* hath pleaded as handſomely as the nature of the thing would admit. "Men of leiſure (he ſays) have amuſed the world with wrangling and "conteſt — by a ſucceſſion of *ſubtil matters* from the earlieſt "times — But it requires only plain ſenſe, and a love truth, "to ſee through the *impoſition* [†]. It is "injurious, he thinks, "to that great man's reputation, to bring in his authority "for a thing which he aſks only by way of a *query*, as if "he had been poſitive;" and that it is "an ill office done "to his memory." But this is a reflexion, which, in my humble opinion, his adverſary did not deſerve: and it ſhould be conſidered in his vindication, that though a *query* may ſhew Sir *Iſaac* not to have been *poſitive* about the *manner* in which his *medium* acts; moſt certainly it doth alſo ſhew, he was not poſitive that no ſuch thing exiſted; eſpecially as he hath mentioned an experiment to prove the exiſtence of a ſubtil matter which has never yet been anſwered [‡]. By what authority then is this writer ſo poſitive? and what will be the conſequence of it, when it *requires only plain*

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[*] See *append.* the note at p. 113.

[†] P. 66.

[‡] See *query* 18.

ſenſe, and a love of truth, to ſee that he is diſputing for one half of Sir *Iſaac Newton*, againſt the other half? The authority of that great man is indeed like to be killed, not by the malice of his enemies, but by the kindneſs of his friends; if ſome of them think an *ill office is done to his memory*, while others think they are offering the only expedient vindication of it.

THIS learned author preſents us with the *attraction of coheſion*, as *an univerſal phænomenon, that ought to ſilence the advocates for material cauſes in all caſes* [*]; and *promiſes to be ſilent, if all the philoſophers upon earth can account for it, otherwiſe than by the power of the Deity immediately intereſted* &c. He judges it *very unartful to ſuppoſe the Deity employing one part of matter to move or direct another part of it* [†], though we ſee it done every day of our lives. — And that no *ſubtil matter* can act as the *cauſe* of *gravity*, unleſs it *knows* what it is doing [‡]. Theſe and ſome other *difficulties* of the ſame ſize, he thinks to be ſo great, that *there is no ſubterfuge* [**]: though it might eaſily be ſhewn, there is not one caſe of any concern rightly ſtated throughout his whole book; and that every article he has built upon is confuted by experience. Theſe conſiderations, I preſume, tempted Mr. *Maclaurin* to paſs ſentence upon his whole ſyſtem in theſe words — "He has done this valuable ſervice, that while "he vainly imagined he improved or compleated it, he really "opened up the fallacy, and reduced it to an abſurdity."

I propoſed it as a queſtion, whether attraction be a *material* force or an *immaterial* one? and we have now conſulted thoſe writers, who ought to have ſettled the point for us. If Sir *Iſaac* hath really *eſtabliſhed* any thing on either ſide, in regard to phyſical cauſes, it is aſtoniſhing his followers have not fixed upon it, and recommended it to the publick with one conſent; eſpecially if there be any thing of importance depending upon it. But if, on the other hand, the ſentiments of their maſter have given occaſion to theſe diſputes, and his writings have furniſhed them with arguments on both ſides; then he himſelf is chargeable with ſome inconſiſtency; and a general agreement among them, in ſuch a caſe, would be as much to be wondered at. That this latter is the true cauſe of all their diſagreement, will be evident to any reader, who is not ſo far influenced by the current authority, as to be deterred from making uſe of his own reaſon. For if you learn from one page, that it is part of the buſineſs of a philoſopher *to unfold the mechaniſm of the world* [*], and that an *ætherial medium* may *ſuffice* to *impel* bodies [†]; in another it is hinted to you, that the ſmall particles of bodies may have certain *powers* by which they *act at a diſtance* — *by attractions* [‡]. If you are informed in one place, that when the rays of light are reflected from the *ſecond ſurface* of a glaſs laid upon an *exhauſted receiver*, this *total reflexion* ought to proceed from the *vigour* and *denſity* of the *medium beyond the glaſs* [**]: only obſerve where the ſame experiment is mentioned in another place, and you will find, the light is now *drawn* back, and that, by the *power of the glaſs*, there being *nothing elſe to turn it back* [††]; though a while ago there was a *medium* to perform this, endued with *vigour* and *denſity*. It is ſuggeſted, that this *medium* may act upon light ſo as to *reflect* and *refract* it [‡‡]. and that the *light* in its turn may re-act upon the medium ſo as to *ſtir up vibrations* in it: but ſoon after, it becomes

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[*] P. 62. [†] P. 49. [‡] P. 117. [**] Ibid.

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[*] Opt. 3d edit. p. 344.
[†] Q. 21.
[‡] Q. 31.
[**] Q. 19.
[††] Q. 29.
[‡‡] Q. 18. 20.

" inconceivable, how two æthers can be diffuſed through all " ſpace, one of which acts upon the other, and by conſe- " quence is re-acted upon, without retarding, ſhattering, " diſperſing, and confounding one anothers motions [*]."

I could multiply inſtances of this ſort, wherein the celebrated author has pulled down with one hand, what he had built up with the other: but if men will dare to uſe their own reaſon, as I ſaid before, they may eaſily obſerve theſe things for themſelves.

If we go from Sir *Iſaac* to his followers, there the confuſion will be ſtill more manifeſt. Drs. *Cotes*, *Clarke*, *Derham*, *Keil*, *Friend*, *Deſaguliers*, Mr. *Rowning* &c. inſtruct us, that *matter* has *powers*, *forces*, *principles*, *affections*, *properties*, *impreſſed* upon it, *ſuperadded* to it, or *inherent* in it; and that God, when he created the world, *inſpirited the materials of it with an active quality*. This was the original doctrine of the mathematic philoſophy, and the ſenſe in which it was firſt embraced by the learned. As it gave birth to many ill-favoured reflexions, it is now almoſt out of faſhion; and Mr. *Maclaurin* riſes up to vindicate Sir *Iſaac*, by a ſubſtitution of his ſubtil *æther*, as the mechanical and immediate cauſe of all that had been falſly imputed to *attraction* by *unſkilful* men. This ſtirs up the indignation of another; who out of the higheſt regard to the *memory* of Sir *Iſaac*, pulls this vindication of him all to pieces, repreſents it as worſe than none at all, rejects all *ſubtil matter* in the lump, and recommends the *immediate influence of the Deity*, as the grand diſcovery, and the only cure for all diſputes. But for his pains, he is inſtructed in his turn, that his own labours have only *ſerved to open up the fallacy of*

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[*] P. 339.

his ſcheme, and reduce the whole to an abſurdity. There have been heavy complaints, that the philoſophy of Sir *Iſaac* hath been *depreciated* and *even ridiculed**. And is it not enough to diſcompoſe the muſcles of an hermit, to ſee men thus notoriouſly contradicting one another, and all gravely pretending to *authority* and *demonſtration!* They tell us, there has been a great *diſcovery* of late years in natural philoſophy; it having been found at length, after the world had been in ignorance for many ages, that all matter is endued with *attraction.* If you aſk them what they mean by it; it is— an innate virtue or affection of matter; while others affirm, matter can have no ſuch affections. It is the moſt ſimple of *cauſes*, and an *effect*, the cauſe of which is unknown; it is owing to the agency of a *ſubtil medium*; and it is effected by the *immediate influence of the Deity:* and if you do not believe this principle, and make uſe of it to *explain* every thing, you are out of the faſhion, and what you have to ſay will be very coldly regarded.

As we cannot poſſibly believe *all* theſe opinions, we are not bound to believe any one of them upon the bare *authority* of Sir *Iſaac Newton.* If we are to receive one of his opinions in this way, why not another? the authority which is broken through in one article, will at leaſt be queſtioned in every other. If it be ſaid, we have reaſon to prefer ſome of his ſentiments to others; then we are influenced, not by authority, but by reaſon or evidence; and hitherto I would willingly bring this matter. Reaſon and evidence muſt determine us at laſt, though the fame of Sir *Iſaac Newton* were as univerſal now as that of *Ariſtotle* was formerly. His warmeſt friends take this liberty with him. Mr. *Maclaurin* rejects his immaterial powers *acting at a diſtance*; Mr. *Baxter* makes as free with his medium, yet is greatly diſpleaſed with his adverſary for leſſening Sir *Iſaac*'s authority. But they treat the publick with ſome diſingenuity, if they would overbear the judgment of others by that authority, which, as it appears from their own practice, hath had ſo little influence upon themſelves. They chuſe their own ſentiments, as inclination or paſſion directs; and then deſire us quietly to reſt upon the authority of Sir *Iſaac*; though one of theſe has robbed him of his *attraction*, the other of his *medium*; and thus, between them both, they have left us nothing to follow.

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* Philoſ. Diſcov. p. 110.

If the learned were but once perſuaded, that God doth govern the natural world by a delegation of material inſtruments, which ſeems to have been *one* of the opinions of Sir *Iſaac*, at leaſt, it was an opinion held by Mr. *Maclaurin* in his name; and could be brought to ſee any errors in the doctrine of reſiſtance; ſomething, I am convinced, might yet be done, either in this or the ſucceeding age, to render natural knowlege more ſerviceable to people of all claſſes than it is at preſent; chiefly, becauſe the enquirers of theſe times would no longer have their hands tied up by an imaginary infallibility in thoſe who have gone before them; the admitting of which has always been attended with fatal effects: they might then reject ſuch principles as are manifeſtly falſe, and *put a ſtop to their enquiries*, and take advantage of the reſt in common.

It is ſtill believed however by very many, either that matter, though inert, is endued with active qualities; or that the influence of the Deity is immediate in the production of all natural effects. By the former of theſe poſitions, we allow to dead matter a power that is denied even to God himſelf[*]: by the latter of them, we are directed to read nature backward; to begin where we ought to have ended; and in ſupport of ſuch procedure, are obliged to annihilate the far greater half of the creation. I ſhall therefore go on to examine, how far theſe poſitions are ſupported by mathematical evidence.

CHAP. IV.

The attraction of gravity, *underſtood as an* univerſal property *or* quality *in the parts of matter, hath received no proof from* geometry.

WE have been aſſured from every quarter, that the modern doctrine of phyſical cauſes has all the evidence that can be deſired from experiment, and is abundantly confirmed by the moſt ſtrict mathematical reaſoning. That this doctrine deduced analytically from obſervation; then applied ſynthetically to the explication of the various phœnomena: and its impregnability in theſe reſpects has been boaſted of, I will not ſay inſolently, but confidently enough. I am ſure, by all its admirers great and ſmall, from the learned, who think it reſts on the firm baſis of geometry itſelf, down to our mere *Engliſh* mathematicians, who declare it as their opinion, that "*never a philoſopher before* Newton *ever took*

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[*] Omnipræſens eſt non per *virtutem* ſolam, ſed etiam per *ſubſtantiam*: nam virtus ſine ſubſtantia ſubſiſtere non poteſt. *Newt. princip.* ſchol. gen.

“ *the method that he did — that it is a mere joke to talk of a* “ *new philoſophy — and that in theſe unhappy days of igno-* “ *rance and avarice*, Minerva *has given place to* Pluto,” meaning *Plutus* [*].

THESE pretenſions, whether of the learned or unlearned, deſerve a ſerious examination. Experiment is nothing leſs than matter of fact, which if not miſrepreſented, is the beſt ſort of argument in the world: and a *mathematical* concluſion, if deduced from real data, is not eaſily overthrown. Something has already been ſaid of mathematical evidence, in the former part of this treatiſe; therefore I have the leſs to ſay of it in this place. And indeed, very little need be ſaid, if the theory of reſiſtance be a fallacy, as I have fully proved it to be; for *that* is the thing generally aimed at by thoſe, who ſpeak of mathematical demonſtrations. It may nevertheleſs be uſeful to remark, that no phyſical principles whatever can poſſibly be collected from geometry. Every particular ſcience hath principles peculiar to itſelf, and independent of every other. No example can be given of the contrary, within the whole circle of the ſciences. How abſurd would it appear, if we were told of the muſical principles of phyſic, the medicinal principles of the civil law, the grammatical principles of aſtronomy? &c. And mathematical principles of natural philoſophy, if *phyſical cauſes* are ſuppoſed to be included, will be equally unnatural; as the moſt ſkilful mathematicians have been ready enough to confeſs. “Geometry, ſays Mr. *Maclaurin*, can “be of little uſe in natural philoſophy, till data are collected “to build upon [†].” Theſe data, I preſume, are to be obtained from natural philoſophy, as a ſcience circumſcribed within its own proper bounds. A method of inveſtigation, ſtrictly phyſical, ſhould firſt be ſubmitted to; and the reſult of that be examined and ſettled, prior to all that can be done in geometry; the application of which, may be of excellent uſe to illuſtrate and adapt to particular caſes what hath gone before; but will add neither demonſtration nor confirmation to it. For a geometrician can work with imaginary or hypothetical forces as well as with real ones; the operation will go on as ſmoothly, and the concluſion come out as readily in one caſe as in the other. No man ſeems to have been better perſuaded of this, than Sir *Iſaac Newton* himſelf. His followers indeed will aſſure us, he has undeniably proved one ſpecies of attraction to be diffuſed through the whole planetary ſyſtem *. But the author himſelf knew better. He declares more than once, that the principles, laid down by him in his demonſtrative work, were not phyſical but purely mathematical †, as the *title* implies: and with regard to gravity or attraction in particular, he is ſo far from pretending to have demonſtrated the exiſtence of any real phyſical cauſe under that term, that his definition of it is ſo looſe, as to leave us quite at liberty about it. We may take it as a drawing, an impulſe, or a tendency of any kind toward a centre. When he conſidered it phyſically, he thought a medium might ſuffice to *impel* bodies, and anſwer all the purpoſes of that attraction, which as it ſtands in his principia, is a cauſe barely hypothetical. Should it be imagined, that attraction, as a cauſe, power, or principle, had been eſtabliſhed by demonſtration; the author will be ſet in a very diſadvantageous light, who could firſt *demonſtrate* attraction, and then *enquire* about it.

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[*] See the preface to *Emerſon*'s treatiſe on *mechanics*. The book is very ingenious and uſeful in its way, and the author appears to underſtand his ſubject; but when he decides thus magiſterially upon philoſophy in general, it is — *ſutor ultrà crepidam.*

[†] P. 35.

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* *Friend.* Chym. Lect. p. 180.

† P. 356.

BUT there is one circumſtance that will put this whole affair out of doubt. It is well known, that the attraction ſuppoſed in the principia, is mutual between all bodies whatſoever. If the earth attracts the moon, the moon in its turn attracts the earth; if the ſun attracts the planets, the planets alſo attract the ſun; and this attraction always follows the proportion of the quantities of matter in the attracting bodies. As a neceſſary conſequence of this, the ſun will be perpetually ſhifting its place, and be moved ſometimes to this ſide of the common center of gravity, ſometimes to that, as he happens to be influenced by a different ſituation of the planets [*].

NOW I beg leave to compare this with what is ſaid of an ætherial medium in the treatiſe of optics. This medium is ſuppoſed to be *rareſt* at the body of the ſun; but to increaſe in denſity through all the diſtances from the ſun to Saturn and beyond; and that it may ſuffice to *impel* bodies from the denſer parts of the medium toward the rarer, with all that power which we call gravity [†]. All this is very juſt: the preſſure of ſuch a medium will undoubtebly be greateſt on *that ſide* of the planets, which is turned *from* the ſun; and all bodies will naturally be carried to that ſide, where the preſſure is weakeſt; that is, *toward* the ſun. But what is become of the ſun's *mutual gravity* in ſuch a caſe? for if he gravitates toward the planets, we muſt contradict this mechanical rule, and ſay, bodies will be impelled from the rarer parts of the medium toward the denſer; without which, the ſun, being already in the rareſt part, muſt for ever be at reſt. Sir *Iſaac* either did ſee this conſequence, or he did

[*] Sol, pro vario planetarum ſitu, in omnes partes movebitur. *Princip.* p. 374.

[†] Q. 21.

not. That he did not ſee the plaineſt conſequences of his own reaſoning, few will be ready to admit: if he did, he gave up mutual gravity to all intents and purpoſes; but this he never could have done, had he thought it to have been mathematically demonſtrated.

I hope I ſhall not be miſunderſtood in this affair. It appears to me, that gravity is no property of matter, becauſe it is not univerſal; and I have compared ſome paſſages, to ſhew it was not univerſal in the opinion of Sir *Iſaac* himſelf; provided only he ſaw the conſequence of his own reaſoning, which will hardly be diſputed. But while I am perſuaded, that the ſun neither does, nor can poſſibly, gravitate toward the planets, for the very reaſon given by Sir *Iſaac Newton*, I am far from denying that the planets tend toward the ſun, and toward each other: it is highly reaſonable, with ſome proper reſtrictions, they ſhould do ſo; and experience, I believe, will convince any aſtronomer of the fact. As the world ſtands indebted to the genius of that great geometrician for this diſcovery, let the learned obtain from it what light they can in aſcertaining the phœnomenæ, and let him have all the honour of it. But never let it be a pretence for ſaddling us with occult powers in ſolid matter; if his followers make that uſe of it, they will gain no credit to their maſter in the end; and hitherto they have gained but little to themſelves by it, as it muſt have appeared from what hath been ſaid; in all which, I hope there hath been on my part no mixture of envy or prejudice; unleſs matters of fact, and plain argumentation, are ſo to be interpreted.

We are to conclude then, that the attraction of gravity, underſtood as an univerſal property of matter, is void of all geometrical evidence. If Sir *Iſaac Newton* hath left this affair undecided, no other geometrician, of this age or the next, is like to ſupply his defects: and yet every ſmatterer almoſt in natural philoſophy is perſuaded he can make it out againſt all oppoſition. The ground and reaſon of which miſtake I apprehend to be this; that many of our geometricians, ambitious of dictating to us about the cauſes and firſt ſprings of nature, while their art can reach only to the *meaſure* of ſome of its *effects*, have not been careful to diſtinguiſh, how far a mathematical concluſion will extend, and how far not. Hypothetical forces or real ones, as it was obſerved above, will equally afford matter for an aſtronomer to work upon [*]. For example, if the moon, as ſhe moves in her orbit, is imagined to be influenced by forces acting in lines which tend toward the centers of the earth and ſun; then the different inclinations of her orbit to the ecliptic, the irregular motion of her nodes, her retardation about the quadratures, her acceleration about the conjunctions &c. may follow by the rules of geometry. Upon theſe principles, Sir *Iſaac Newton* is univerſally allowed to have accounted for the lunar irregularities with great ſagacity, and, as an aſtronomer, to have left that matter in a much better ſtate than he found it; though it is not yet perfected. But what theſe forces are in ſpecial, and in what manner they act; whether as an active immaterial virtue, exerted through a void ſpace, *from* the centers of the earth and ſun; or as a preſſure of ſome etherial medium acting in lines *toward* thoſe centers; none of his reaſonings have determined for us. So far from it, that we find his principia inclining to one ſide, and his phyſical queries to the other. And I may appeal to the judgment of any ingenuous man, ſufficiently verſed in mathematical ſtudies, whether the phœnomena above-mentioned may not ariſe from a preſſure *behind*, as well as from an attraction *before*; and whether Sir *Iſaac*'s geometrical reaſoning will not be as concluſive in the one caſe as in the other? How comes it then to have been publiſhed to the world, that "one ſpecies of attraction hath been undeniably proved "to be diffuſed through the whole planetary ſyſtem?" This having been no more proved by any of his arguments, than that one ſpecies of *impulſe* or *preſſure* is diffuſed thro' the whole planetary ſyſtem; and for the truth of this, I may refer to the *definition*, where the terms *attraction* and *impulſe* are taken indifferently, and are to be ſo taken throughout the whole book; otherwiſe this can anſwer no purpoſe as a *definition*. That ſome force prevails, and in ſuch particular directions, is capable of demonſtration: but the reaſoning and obſervation, which only prove the exiſtence of ſome force in general, will never demonſtrate that of attraction to be the force in particular. So that nothing farther need be ſaid in this way. Let us now go on to experiment.

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[*] Neque neceſſe putant, ut hypotheſes iſtæ veræ ſint, imo ne veriſimiles quidem, ſed ſufficit hoc unum, ut calculum obſervationibus congruentem exhibeant. *Horrocc.* Op. Poſt. 179.

CHAP.

CHAP. V.

The attraction of gravity, underſtood as an univerſal property *or* quality *in the parts of matter, is not agreeable to* experiment *and* obſervation.

NO experience has hitherto ſhewn us, that what is called the *attractive force* of the ſun and planets, is anſwerable to their quantities of ſolid matter. Their bulk, as computed from their reſpective diſtances and apparent diameters, is far from yielding a proportion of gravity ſo uniform as might have been expected. Gravity toward the earth proves to be much greater in proportion to the bulk of the earth, than gravity toward the ſun, or any of the primary planets. This ſeems to be a great difficulty in the hypotheſis of gravity. But how eaſily is it reconciled, if we are allowed to alter the *denſity* of the heavenly bodies, and by this means bring their quantities of matter to an agreement with the hypotheſis! The *fiat* of a favourite philoſopher can ſo reduce the denſity of the ſolid matter in the body of the ſun, that the denſity of the earth ſhall be *four times* greater; and then the attractive power of the ſun ſhall exactly anſwer to his quantity of ſolid matter: and the ſame liberty muſt be taken with the other great bodies of the ſolar ſyſtem. Their denſity muſt be accommodated to their actractive powers: then if their attractive powers be taken for granted, their denſities will paſs for a *diſcovery*. Thus great men amuſe themſelves and the world by arguing in a circle, or proving the truth of a propoſition by the concluſions they have drawn from it: for unleſs you admit of this denſity, which arbitrarily, and without any obſervations to ſupport it, is accommodated to the hypotheſis of gravity; that hypotheſis will labour under a diſagreement with obſervation.

THAT there may be ſome ſhew of experience however in all this, it is intimated that the ſun muſt needs be rarer than the earth, becauſe of the immenſe heat of his body *. But the planet *Jupiter*, whoſe body muſt be exceedingly colder than that of the earth, appears from his attractive power upon his ſatellites † to be much rarer than the ſun, and *Saturn* rarer ſtill; which circumſtances are very unpromiſing; and if gravity be admitted here as the ſole agent, we are conducted to a ſort of philoſophy, that blows hot and cold, againſt all reaſon and experiment. *Des-Cartes* was of opinion, that the denſity of the planets muſt naturally increaſe as they are more remote from the ſun: and ſurely this is more reaſonable than the contrary; it being an obſervation, to the beſt of our knowlege univerſally true, that bodies are rarefied by heat, and condenſed by cold; the ſeeming rarefaction of ice not excepted.

THAT the gravity of bodies is in all caſes as their quantities of ſolid matter, is rendered very doubtful, if not abſolutely falſe, by ſome chemical experiments, and has been doubted of by perſons of no ordinary ſkill in geometry and natural philoſophy. Mr. *Maclaurin*, among the reſt, thinks we can affirm this, only when we compare bodies *of the ſame kind* ‡.

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* Nam per ingentem ſuum calorem ſol rareſcit. *Princip.* p. 372.

† The method Sir *Iſaac* made uſe of to inveſtigate this mathematically, is laid down, in a manner as eaſy as the thing is capable of, by Dr. *John Clarke*, in his *demonſtration of Sir* Iſaac Newton'*s principles of philoſophy*. 8vo. p. 301. &c. conſult alſo Mr. *Maclaurin*'s account &c. p. 288. &c.

‡ This agrees exactly with a definition given by *Plato* — ωσπερ εν τω Τιμαιω τυγχανει γεγραμμενον, βαρυτερον μεν, το εκ πλειονων ΤΩΝ ΑΥΤΩΝ συνεστος. *Ariſt.* de Cœlo. Lib. 4. c. 2.

HOMBERG's experiment on the regulus of antimony, and the ſucceſs of it, is a thing generally known. He expoſed ſome of this matter to be calcined by the great burning glaſs of the duke of *Orleans*, and found it had gained in the operation one tenth part in weight. *Homberg* made this experiment and ſome others like to it, with the expectation of being able in due time to produce gold. But *truth* is of much greater value, and if we can produce any of that from it, let us leave all the gold to the adepts. Some relate the experiment thus — If a maſs of regulus of antimony, of a pound weight, be pulveriſed, and calcined at the focus of a burning glaſs of a *Paris*-foot in diameter, the weight of the maſs will be increaſed by one tenth; though during the whole time of the operation, which laſts about an hour, the regulus ſends up a thick ſmoke, and thereby loſes a conſiderable part of its own proper ſubſtance.

THERE are, I think, but two poſſible ways of accounting for this effect. 1. If the quantity of matter be the ſame after calcination, or ſomething leſs (the ſmoke being allowed for) than it was before, while the gravity of the whole is become greater, then the gravity does not follow the quantity, and conſequently it is no *property* of the matter. 2. If there be an increaſe of the maſs, it can be imputed to nothing but the matter of light or fire entangled in its paſſage through the ſubſtance, and ſo fixt in its pores or combined with its ſolid parts, as to gravitate together with it. On this latter ſuppoſition, the matter of fire muſt have a denſity, which will introduce great confuſion into the doctrine of a vacuum. But to come ſtill nearer to the purpoſe; it will alſo be ſaid, that if this fire did not gravitate, till it was fixt in the metal, (and it will be hard to prove that it did) then we have a fluid, which gravitates in ſome caſes and not in others: ſo that the ſame concluſion offers itſelf, which way ſoever the experiment is interpreted. It will be vain to ſuppoſe, that any heterogeneous matter floating in the air, or that the air itſelf, is hurried into the maſs by the action of the fire, and the weight increaſed by this means. For it is known experimentally, that if a quantity of metal be even hermetically ſecured within a veſſel of glaſs to keep off the air and all foreign matter, and the veſſel be placed for ſometime in a ſtrong fire, it will exhibit the ſame effect. I have ſeen the operation performed on two ounces of pewter-filings, hermetically ſealed up in a florence-flaſk, which in two hours gained 55 grains, that is, nearly $\frac{1}{17}$th*: had it remained longer in the fire, it might poſſibly have gained ſomething more. The calx of lead, commonly known by the name of red-lead, is reckoned to gain one tenth; at which rate, 10lb. of fire will be fixed in 100lb. of lead. If this trial were made in ten thouſand different places of the world at once, and repeated an hundred times in a year, no reaſon can be given why it ſhould not ſucceed. But the quantity of fire thus imbibed, allowing the proportion above-mentioned, would amount to 10,000,000lb; which according to the modern law of gravity is more than ought to repleniſh the whole orbit of Saturn. Yet, I preſume, the heavens and the earth would be as plentifully ſtored, to all intents and purpoſes, with this element as they were before: fires would burn, the ſun would ſhine, and electrical experiments ſucceed in all places juſt as they do now.

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* In one experiment of Mr. *Boyle* on copper filings, the increaſe by fire was $\frac{49}{480}$, that is, ſomething better than one *tenth*. In another, an ounce of tin calcined gained a drachm, that is, $\frac{1}{8}$; and ſteel filings more than $\frac{1}{4}$th. See *his experiments to make fire and flame ponderable.*

As a ſequel to what has here been obſerved concerning the impregnation of ſolid ſubſtances with the particles of fire, and particularly that of minium or red lead; give me leave to ſubjoin an experiment of Mr. *De Stair*, which I borrow from the excellent *Niewentyt*. He tells us, that upon heating red lead in a glaſs (from whence the air was exhauſted) by the rays of the ſun collected in a burning glaſs, the veſſel, in which the ſaid red lead was contained, burſt in pieces with a great noiſe *. Now as all exploſions in general muſt be aſcribed either to an admiſſion of the air into a rarefied ſpace, or to what is called a *generation* of it; and as it was not admitted upon this occaſion, it muſt have been generated from the calx within the veſſel: and certainly was ſo, becauſe Dr. *Hales* has made it appear, that this ſubſtance, like crude tartar and many others, will yield a conſiderable quantity of *air* in diſtillation †. What went into the metal therefore as *fire*, comes out of it again as *air*; which in a manner forces us upon a concluſion, of ineſtimable value in natural philoſophy, and ſuch as may carry us very far into what Mr. *Maclaurin* has termed, with great judgment, the *moſt ſublime part* of it. The ingenious experiments of Dr. *Hales* ſeem to have given him a ſight of it; as I conjecture from his having mentioned on this occaſion, the *aerial particles of fire* ‡. The force of all the fulminating powders, the violent ebullition of ſome mixtures, the ſudden accenſion of others, the inflammability of oils and other combuſtible matters, together with the taſte, ſtrength, and fermentation of liquors, the operation of menſtruums &c. do all ſuggeſt the ſame thing; and might, with great appearance of reaſon, be deduced from one and the ſame principle, if this were a proper place for enlarging upon it.

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* P. 314.

† Veg. Stat. p. 287.

‡ Ibid. p. 286.

I had a deſign of bringing in here another ſeries of experiments, to ſhew that the gravity of bodies, where thoſe bodies are of different kinds, is not in the direct ratio of their actual quantities of matter. But theſe are ſo very critical, as to require perhaps a knowlege of the intimate conſtitution of bodies to judge of them properly: and my concluſion, ſuppoſing it to be true, would not be very obvious. It is therefore better wholly to omit them; for why ſhould we lay a ſtreſs upon any thing not ſufficiently clear and plain, when there is evidence ready at hand, the force of which may be apprehended by readers of all claſſes? It is wiſely ordered by the divine providence, that what is moſt neceſſary to be known of nature, is generally the moſt eaſy to be underſtood: and if I aſſert that "gravity is no univerſal "quality of matter, becauſe all matter does not gravitate," I may have recourſe to a phœnomenon of equal extent with the creation itſelf; and which, without an hyperbole, is as clear as the ſun at noon-day.

Gravity, it has been ſaid*, is the "quality of all bo"dies on which any experiments have been made;" and that as bodies near the earth gravitate toward the earth, ſo all "bodies in the heavens gravitate toward the ſun †." But if we believe this, there is an end of all experience: for, ſuppoſing this to be true, not one atom of light could ever come to us from the body of the ſun. Who would undertake to prove, that the air of our atmoſphere did gravitate toward the earth, if it were inceſſantly flying off from it toward the moon and the other planets? This is the caſe with the atmoſphere of the ſun. A flood of matter is ſent off every moment with immenſe rapidity, from his orb, in a direction oppoſite to that of gravitating bodies; and in ſo large a quantity, that no ſpace however ſmall could be aſſumed within the whole ſolar ſyſtem, where the point of a needle could be oppoſed to the ſun, without ſtopping ſome thouſands or millions of the particles thus ſent from him. So long as the ſun ſhines, a man muſt do violence to his own ſenſes, if he can believe a centripetal tendency to be the quality of *all* matter; when the matter, void of that quality, is in all appearance as far ſuperior in quantity to the matter poſſeſſed of it, as the whole globe of the earth to an ordinary mountain. But be the quantity great or ſmall, if the ſolar light is only allowed to be a material ſubſtance, the concluſion will hold good.

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* Princip. Lib. 3. prop. 6. Cor. 2.

† Ibid. p. 469.

THIS grand objection to the gravitarian hypotheſis has never been ſtated, or directly replied to, in the philoſophical works of Sir *Iſaac Newton*; and is generally paſſed over in ſilence by all his proſelytes; though there is nothing more worthy of admiration, nor more beneficial to mankind, in the whole œconomy of created things, than the conſtant emiſſion of light from the ſun.

THERE are indeed two arguments, if they can be called ſuch, by which our attention ſeems to be tacitly called off from this difficulty. They are certainly of no great importance in themſelves; but by paſſing through the pen of Sir *Iſaac Newton*, they are rendered too conſiderable to be neglected. The firſt is a poſition borrowed from *Ariſtotle* and *Des-Cartes*, that "matter differs from matter only in form, "retaining all other properties in common [*]." But this cannot be admitted without ſome proof; becauſe it is the very point in queſtion. That gravity is one of thoſe properties which are retained in common, though the form of the matter be different, is an article, which has never yet been proved; and I humbly think, never will be, the propagation of light from the ſun being a poſitive inſtance to the contrary. It would be weak to oppoſe an unſupported aſſertion, a mere logical ſubtilty, to ſo plain and important a matter of fact, the concluſion from which is ſo viſible, that nothing but art or prejudice can avoid it: it depends not on *words*, but on the viſible conſtitution of *things*, and offers itſelf to the common obſervation of all men in the great out-lines of nature.

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[*] P. 368.

Another method of evading this difficulty, is, to repreſent the element of fire, or matter of light, as a mere nothing; a ſubſtance, which may occupy a ſpace in ſo ſingular a manner, as to leave it *empty*[*]: and it ſeems to be queſtioned, whether a reader will recollect that there is ſuch a fluid as that of light in the ſolar ſyſtem[†]. Where we might have hoped to receive from ſo maſterly an hand ſome inſtruction concerning the nature and uſes of this wonderful fluid, we are amuſed with a long account of tranſmutations, unnatural and romantic, founded on an experiment of Mr. *Boyle*, in which he thought he had obtained fixed earth from water. But *Boerhaave*[‡] carefully examined this, and found it to be a miſtake. Hence however Sir *Iſaac* inferred, that as water is turned into earth, ſo groſs bodies are turned into light, and light into bodies[**]: though by a principle adopted on another occaſion, all this is rendered very improbable, if not altogether impoſſible. He is of opinion, that the primitive particles of bodies will "compoſe bodies of one and the ſame nature "and texture in all ages [*];" with which all tranſmutations whatſoever are inconſiſtent. In ſhort, the matter of light ſeems to have been but a troubleſome gueſt in the mathematic philoſophy, though the author of it was indebted to it for the beſt and moſt durable part of his reputation. And long may it laſt; it is no intereſt of mine to wiſh that the fickleneſs and inconſtancy of mankind may ever deprive him of it. He aſks "Is not fire a body heated ſo hot, as to emit light copiouſly? for what elſe is a red-hot iron than "fire [†]?" Let us anſwer this, by putting a like queſtion concerning the element of water. "Is not water a body "wetted ſo much, as to wet every thing elſe copiouſly? for "what elſe is a wet ſponge than water?" In this latter example every perſon will allow the ſponge to be a diſtinct body from the water, containing that element in its vacuities. Now fire is as truly an object of ſenſe as water; and hath as many properties to diſtinguiſh it as a fluid. What can a red hot iron be therefore, but *iron and fire* [‡], that is, iron with the element of fire in it; as boiling water is fire and water; and may be demonſtrated to be ſuch, by including it in an exhauſted receiver, as well as by ſome other methods; though, I preſume, the epithets *red hot* might accord better with the inclinations of Sir *Iſaac*, than a noun ſubſtantive would have done.

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[*] *Empty celeſtial ſpaces.* Opt. Q. 21.

[†] Si FORTE vapores longè tenuiſſimos, & trajectos LUCIS radios excipias. p. 328. Princ.

[‡] See *Shaw*'s edition of *Boerhaave*'s chemiſtry. V. 1. p. 471.

[**] Mr. *Boyle* has an hydroſtatical experiment to prove, that when the weight of any metal is increaſed by fire, the fire is *not turned into metal.*

ALL theſe things being conſidered, I beg leave to propoſe it as a *query* of ſome importance, whether Sir *Iſaac* did not think it his intereſt to get rid of this powerful element, or at leaſt, to reduce it ſo low in the eſteem of his readers, that it ſhould never be able to do his ſyſtem any harm. As for argument, there is little or none in the caſe: had there been any, his penetration would ſoon have ſeized upon it: therefore *Boerhaave*, *Graveſande*, *Niewentyt*, and others, embraced a contrary opinion; holding fire to be an element *ſui generis*, and rejecting the whole doctrine abovementioned, without beſtowing upon it, to the beſt of my remembrance, any ſerious refutation; though they all concurred unanimouſly in admiring Sir *Iſaac* as a moſt excellent geometrician. And indeed it is not worth diſputing about: for to ſay nothing of chemiſtry, the experiments of electricity, how great ſoever the prejudices of the learned may be at preſent, will in due time get the better of ſuch unſerviceable ſpeculations. There have already been ſome laudable attempts in this way, though they are but few; and ſome of the gentlemen who have been engaged in this ſtudy, ſeem to be terribly affrighted at the conſequences of their own diſcoveries, treating the element of fire with as much caution, as if they were touching it with their fingers. The ingenious Mr. *Watſon*, whoſe experiments are very curious, inclines to the elementary ſide. Dr. *Hill*, after the examples of *Boerhaave*, *Homberg*, and the younger *Lemery*, does the ſame, in a learned work entitled — *Thoughts concerning God and nature.* He has ventured to add ſome ſpirited reflexions, in a way peculiar to himſelf, on the modern philoſophy of fire; which, I ſuppoſe, the facts he is maſter of will ſufficiently juſtify. What he has ſaid in his 5th book, from the beginning of the 3d, to the end of the 7th chapter, deſerves well to be conſidered: his hints, though very brief, contain in them more truth, in my humble opinion, than any eſſay publiſhed on the ſubject ſince the cultivation of electricity in *England*. Others there are again, equally reſpectable for their ingenuity and induſtry, who are very unwilling to admit the agency of an intelligible fluid, ſuch as fire is. They will perſuade us, it is improper to call the electrical fluid by that name; it being not fire, but the ſubtil æther ſo frequently ſpoken of by Sir *Iſaac Newton* *. The negative part of their opinion they thus illuſtrate —— as air cannot properly be called ſound, ſo neither can this fluid be called fire. Air, they ſay, raiſes the idea of ſound, and this fluid cauſes a body to ſhine or be on fire: but as air cannot be called ſound, merely becauſe it raiſes the idea of ſound; ſo this fluid cannot be called fire, merely becauſe it excites fire. Any reader who is poſſeſſed of a little logic, will immediately perceive this to be, not an argument, but a tranſpoſition of terms. For the parallel, in their way of drawing it, is really this — as the air, that cauſes bodies to ſound, is not ſound; (it ſhould have been, *is not air*;) ſo fire, the fluid that cauſes bodies to burn and ſhine, *is not fire:* — the inconcluſiveneſs of which is ſufficiently evident. Fire, with all its old properties, and ſome new ones, is the agent diſcoverable by ſenſe in electrical experiments: this fluid, which *appears* in all the experiments, they over-look; and would ſolve them all by another fluid, which (like the *fifth element* of *Ariſtotle)* never yet appeared, nor ever will in any one of them. Electricity may well be dark and difficult, if ingenious men refuſe to be governed by their own eye-ſight, becauſe it would ſuggeſt, even to the meaneſt capacity, ſome principles differing from the moſt eminent geometrician of their own country; who, being but a man, was liable to error like other men; if not, I am greatly to be blamed for what I have written, and for concluding, as I take the liberty to do without any fear or reſerve, becauſe I could prove it by numberleſs experiments, that fire is the moſt powerful agent in nature; that the whole heavens, as it is manifeſt to ſenſe, are repleniſhed with the ſubſtance of light; and what is above all to be regarded, that it iſſues from the ſun's orb in a direction contrary to that of gravity: that therefore, Sir *Iſaac Newton*'s univerſal law is falſe by experience.

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[*] Opt. p. 376.

[†] Q. 9.

[‡] Μιξιν δ' ειναι ΔΥΟ η και πλειονων ΣΩΜΑΤΩΝ ως επι του ΠΥΡΟΣ εχει και του πεπυρακτωμενου ΣΙΔΗΡΟΥ. *Stob.* Ecl. Phyſ. Lib. 1. c. 20.

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* Obſervations on a ſeries of electrical experiments. By Mr. *Wilſon* and Dr. *Hoadly*. p. 69, 70.

THE ſame may be concluded from another conſideration of much weight, and almoſt as plain as the foregoing.

THE materials of this terraqueous globe are generally agreed, both by the ancient and modern enquirers into nature, to have been once in a ſeparate and diſorderly ſtate. The ſacred writings are known to have aſſerted this very expreſſly; and to have added withal an account of particulars, ſo far as it is needful for us to be acquainted with them. Between this account, and the heathen traditions relating to the ſame affair, there is a ſurpriſing agreement; of which ſo many examples have already been collected by *Grotius*[*], and with ſo much learning and judgment, that very little needs to be added to what he has ſaid. Taking it then as granted, that the parts of this earth did once ſubſiſt as a formleſs and incoherent *chaos*, a queſtion will naturally ariſe, by what phyſical means or agency, in ſubordination to the divine power, they were brought together, and put into the orderly form in which we now find them? *Ovid* ſays it was by a *melior natura*; which is a phraſe without a meaning, and anſwers no end but that of filling up his verſe. *Des-*

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[*] Grot. de Verit. L. 1. ſect. 16.

Cartes ſuppoſes the world to have *put itſelf* into order, by an imaginary motion of his *vortices*. And Sir *Iſaac Newton* tells us, "the globe of the earth and ſea affects a round figure by the mutual attraction of its parts by gravity[*]."

To know whether this laſt ſuppoſition has any truth in it, we muſt have recourſe to obſervation. If the parts whereof the ſeveral ſtrata of the earth conſiſt, and which appear to be no other than the ſediments of water, did originally ſubſide by the agency of gravity; the ſtrata ſhould lie in the order of their ſpecific gravities; and the extraneous bodies buried in them ſhould have the ſame ſpecific gravity with the ſtrata wherein they are found.

ALL this Dr. *Woodward* aſſures us is agreeable to fact. "This ſubſidence happened generally, and as near as poſſibly could be expected in ſo great a confuſion, according "to the laws of gravity; *that* matter, body or bodies, which "had the greateſt quantity or degree of gravity, ſubſiding "firſt in order and falling loweſt; that which had the next, "or a ſtill leſſer degree of gravity, ſubſiding next after and "ſo on[†]." — "the lighter ſhells fell amongſt the lighter "matter, the heavier ſhells amongſt the heavier[‡];" and in a word, all the materials of this earth are generally ſo diſpoſed as they ought to have been by the agency of gravity. All this is aſſerted with the greateſt confidence; and by a writer too, whom we muſt allow to have been well acquainted with the ſtructure of the earth. But it is ſo contrary to obſervation, that every common labourer, who has aſſiſted in the turning up of a ſtone-quarry, or the ſinking of a coal-mine, muſt know it to be falſe.

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[*] Opt. p. 370.

[†] *Nat. Hiſt.* of the earth. p. 75.

[‡] *Ibid.*

THE bowels of the earth have been purpoſely examined with this view, nearly to the depth of 200 feet; and the loweſt ſtratum hath been found lighter than the uppermoſt that lay immediately under the turf. A deſcription of the ſtrata, found in a coal-pit in *Staffordſhire*, was communicated to the royal ſociety by Sir *Hans Sloane*, and the ſpecific gravity of the ſeveral ſpecimens having been examined by Mr. *Haukſbee*, he made the following report — that "the gravities of the ſeveral ſtrata are in no manner of order, "but purely caſual, as if mixt by chance*." And as to foſſile ſhells, bones of animals, mineral concretions &c. they are depoſited indifferently at all depths, and are to be met with in all kinds of matter. The *echinites*, a foſſile body formed in a ſhell of the cruſtaceous kind, which is very light, is found in chalk, in clay †, and in ſtone. Cockle-ſhells and foſſile-plants are found at the ſame depth; and, not to multiply inſtances, the *pyritæ*, a ſort of metallic nodules, are generally found in *chalk*. I ſelected one of theſe bodies, of a ſpherical form, with ſome of its native chalk adhering to it; and found its ſpecific gravity to be to that of common water, as 4. 59 to 1; nearly the ſame with that of ſome grey lead ore, which I compared with it at a venture, and found to be as 4. 83 to 1. How a body of this weight could be depoſited amongſt chalk by any law of gravity, is to me inconceivable; and Dr. *Woodward*'s motive for ſo ſtrangely miſrepreſenting this whole affair, would have been equally inconceiveable, if he had written an hundred years ago: but at the time his thoughts were employed on the *natural hiſtory of the earth*, gravity was coming into vogue as a new

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* *Phil. Tranſact.* No. 336. p. 541. or *Haukſbee's experiments.* p. 317.
† *Luid. Litolph.* Cl. 6. Art. 926.

primum mobile; and there are few men, who for the ſake of truth will run the hazard of having their literary productions, the fruit of much labour and ſtudy, neglected or evil-ſpoken of as ſoon as they are publiſhed; though in ſucceeding times, when the heat of faſhion is a little abated, they will be reſpected the more for it. If Dr. *Woodward*'s aim was ſuch as I imagine it to have been, he certainly failed of it in ſome degree. The introducing of gravity into his work might gain him many friends and ſome few proſelytes; but it infuſed into others a very ſtrong prejudice againſt him: for this appears to have been the principal reaſon, which moved Mr. *Ray* to reject his hypotheſis of an univerſal diſſolution. He ſuſpected it to be an invention ſubſervient to the new principle of gravity; knowing that the phœnomenon, which he would have ſolved by ſuch a diſſolution, was not generally true, and that we have ſufficient authorities to prove the contrary *.

THOUGH the nature of my ſubject hath obliged me here to make ſo free with Dr. *Woodward* in one article, I have no deſire to leſſen his real merit, which is that of having treated the ſubject of the univerſal deluge in a manner far ſuperior to all writers who had undertaken it before him. But in the article relating to gravity, to ſay the beſt we can of him, he was miſtaken.

HAD the earth been put together in the manner he has ſuppoſed, by the attraction of gravity, the natural order of things would have been inverted, and the œconomy of the world thrown into the utmoſt confuſion. All the water of the globe would have been uppermoſt: all the gold, and other metals, would have ſubſided to the central parts. And altho' the poet has fixed a *ſtigma* on his *effodiuntur opes*, yet had they been carried down to the center, how many hands had been unemployed, and left to idleneſs or miſchief, for want of neceſſary labour. What ſhould we have done for inſtruments of iron and braſs; I will not ſay for warlike and deſtructive purpoſes, but for neceſſary and mechanical uſes? To be ſhort, the diſpoſition of things below the ſurface of the earth is ſo ordered, that mankind may reap the greateſt benefit from it. And does it not plainly demonſtrate at the ſame time, that tho' bodies may fall to the earth by what we call gravity, this gravity is but a partial phœnomenon, and was never employed as a ruling principle in the conformation of this terraqueous globe? If to the facts here collected, we add the denſity of elementary fire as found by experiment, and the perpetual efflux of light from the ſun, the reſult of the whole is — gravity does not prevail as an univerſal principle, either in the heaven above, or in the earth beneath; and conſequently, a ſyſtem of philoſophy, which both ſuppoſes and requires it to be univerſal, hath miſtaken the agency of nature, and is ſo far at leaſt contradicted by experience.

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* *Ray*'s three diſcourſes. p. 167. 4th edit.

CHAP. VI.

The forces of attraction and projection, commonly called central forces, *will not conſiſt with the motion of the* planets, *even upon the ſuppoſition of a* celeſtial vacuum.

I HAVE but one more obſervation to make in regard to gravity. I own it to be ſomething in the nature of a digreſſion, and as ſuch I hope it will be excuſed. This principle then, compounded with a projectile force, will not account for the motion of the heavenly bodies, even allowing the ſpaces in which they move to be void of all reſiſting matter. We are under no obligation to grant this; however let us grant it for argument's ſake, and ſee what will follow.

A body acted upon by two different forces at the ſame time, will deſcribe the diagonal of a parallelogram, whoſe ſides are reſpectively equal to the two forces. Experiment ſhews this to be true; the *application* of it is what I am here to treat of; and I ſhall endeavour to be as ſhort and as plain as I poſſibly can.

THE celebrated author of the principia, as it is univerſally known to all thoſe who have but dipt into natural philoſophy, ſuppoſes a planet to be acted upon by a projectile force, giving it motion in a right line, which makes a tangent with its orbit. This force, once impreſſed, is always to continue by his *firſt law of nature* *. It is alſo acted upon at the ſame time by a centripetal force; which ſome obſervations upon the moon have induced him to believe is the ſame with what is called gravity near the earth's ſurface. By the former of theſe forces alone, it would always proceed in the tangent or right line; by the latter, it would fall ſtrait to the centre; by both of them jointly, it will be gradually bent below the tangent, and in a given time, ſufficiently ſmall, will deſcribe the diagonal of a parallelogram, whoſe ſides are as the two forces. In a ſecond moment of time, it will deſcribe another, and ſo on. Now if theſe parallelograms are imagined to be infinitely ſmall, a ſeries of their diagonals will not ſenſibly differ from a curve: and thus he accounts for the motion of the planets in curvilinear orbits.

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* Sir *Iſaac*'s firſt law of nature is this — *All bodies continue in their ſtate of reſt, or motion, uniformly in a right line, except ſo much as they are forced to change that ſtate by forces impreſſed.*

Prima lex naturæ, quod unaquæque res quantum in ſe eſt, ſemper in eodem ſtatu perſeveret; ſicque quod ſemel movetur, ſemper moveri pergat, nec unquam mutetur niſi a cauſis externis. *Vid.* Carteſii *princip. philoſ.* P .2. ſect. 37.

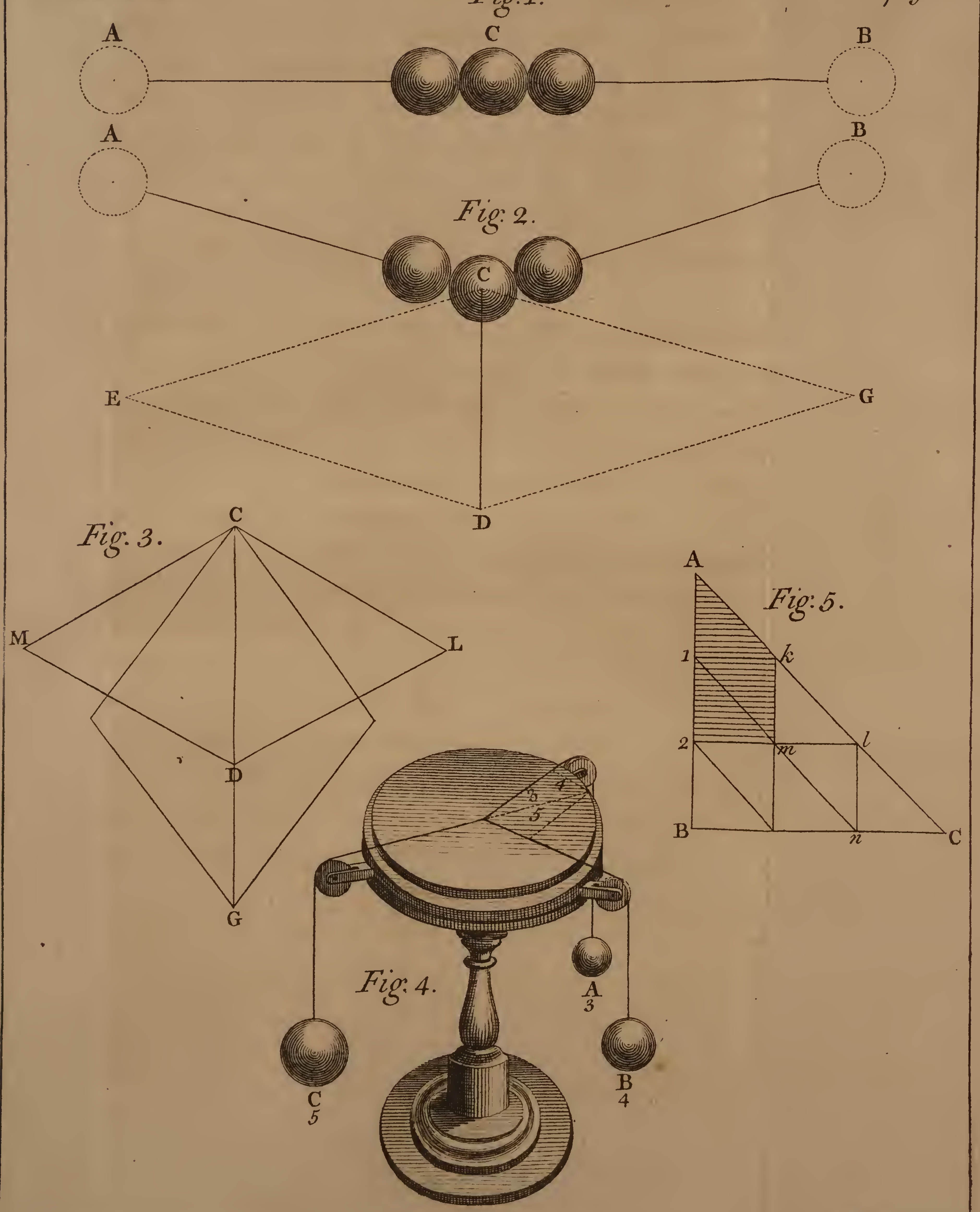
The greateſt adverſaries of Sir *Iſaac Newton* muſt allow the thought to be highly ingenious. A thorough mathematician is ſo ſmitten with the elegance of it, and with the wonderful things he has deduced from it in a courſe of abſtruſe theorems, in which few are able to follow him but thoſe who do it to a degree of enthuſiaſm, that they will very hardly be induced to quit their theories for a while, and condeſcend to examine, how this ſpeculation will conſiſt with practice.

If I had an inclination to multiply words, I might object to the generation of a curve by the diagonals of ſmall parallelograms; becauſe there follows from it this abſurdity, that as theſe diagonals can be conſidered only as right lines, no curve can be compoſed of them, unleſs a curve and a right line are commenſurable; which every geometrician knows to be falſe. It would be idle to inſiſt upon this, becauſe the thing does aſſuredly hold good in nature, whether the *method of infinites* will conſiſt with geometry, or not.

A curve

PLATE II.

page 111.



I. Mynde Sc.

A curve is evidently deſcribed by a projectile; and that projectile appears to be actuated by two forces thus compounded. As far as I am able to judge, there is no reaſon why the orbit of a planet, provided the forces are adequate to the effects, may not be produced in the ſame manner. But I humbly think, the forces of *gravity* and *projection*, which were propoſed long ago with this view by Mr. *Horrox*[†], are inadequate, and unfit for the buſineſs aſſigned them. No *laſting* motion, as it will ſoon appear, can poſſibly ariſe from a compoſition of *theſe* two forces, for the following reaſons.

LET us imagine the two forces to be repreſented by two bodies, A and B (See *plate* II. fig. 1.) and let theſe be made to ſtrike againſt a third body, C, at reſt. Now it is certain, from the laws of percuſſion in bodies not elaſtic, 1. that if A and B are carried with equal quantities of motion toward contrary ſides, and do both impinge at the ſame time againſt C, no motion is produced by it, but all the three bodies remain perfectly at reſt after the ſtroke. This may be laid down as the moſt ſimple caſe. 2. If the angle of their meeting at C be very obtuſe, as ACB (fig. 2.) the motion communicated to the body C will be equal to the diagonal CD; ſo that the whole *ſum* of the force hereby produced, is not equal to either of the forces *ſingly* which produce it, and all the remaining part is loſt. In the firſt caſe, the reſiſtance between the two forces was total; here it is but partial. 3. If the angle of meeting be leſs obtuſe, right, or acute, as in the 3^d figure, the motion produced may be equal to *one* of the forces, as CD, where the angle LCM is 120 degrees (the triangles on each ſide the diagonal being *equilateral*) or greater as CG; but can never be equal to *both*, till they coincide in the ſame right line; which caſe is the reverſe of the firſt, for by ſuch coincidence the communication becomes total, and the reſiſtance vaniſhes.

[†] Teſtantur obſervationes — figuram orbitæ planetariæ eſſe ellipticam — motumque ejus in hoc elliptico inæqualem eſſe, & pro diſtantia ſua a ſole intendi & remitti — *Projiciatur* plumbum aliquod in altum, ſurgit *primò velociter*, *deindè tardius*, dum tandem ſtationarium in terram recidat *continuo velocitatis incremento*, atque ita motum librationis deſcribit — oritur ea libratio, ex *pugnâ virtutis illius* quam manus tua illi infudit, unà cum *virtute telluris* magneticâ, quâ omnia *gravia* ad ſe *attrahit*. — Quid eſt quod *in motu planetarum*, ubi eadem commoditas non deeſt, *cauſam veram* a naturâ ipſâ tot exemplis confirmatam, fictitio circulorum ſomnio commutaremus? *Horroc.* Op. Poſt. p. 181. §. 3. This wonderful adept in aſtronomy flouriſhed towards the beginning of the laſt century, and died at the age of 22.

I ſhall be ſorry if the word *reſiſtance* gives any offence to thoſe, who have been accuſtomed to a different way of reaſoning: but if they can, upon the received principles, diſtinguiſh between *reſiſtance* and a *loſs of motion*, I confeſs it is more than I am able to do. Motion, they muſt allow, is always loſt in the *compoſition of forces*. There is an eaſy way of ſhewing this experimentally, by three weights pulling at the ſame centre with oblique forces. Thus if the weight A (fig. 4.) of 3 pounds, and the weight B of 4 pounds, pull againſt each other at an angle of 90 degrees, they will counterpoiſe a third weight, as C, which is only 5 pounds. The difference, or loſs, is equal to 2 pounds: but how can this be, unleſs the compounded forces 3 and 4 do in ſome manner counteract each other? and what can we call this but *reſiſtance?* the thing will be juſt the ſame, whether the word be admitted or not: a motion thus produced, by a *compoſition of forces*, cannot be laſting, unleſs theſe forces are perpetually *renewed.*

THE application of all this is eaſy enough. The centripetal force upon a planet, having a conſtant ſupply, will be increaſing every moment, and bring the planet nearer to the centre. But the projectile force, originally impreſſed, having no recruit but from the *firſt law of nature*, which is none at all, muſt vaniſh by degrees; and it makes no difference in the argument, whether you ſuppoſe it to vaniſh in ten years, or in ten thouſand. Hence it is impoſſible for a body actuated by *theſe* forces, to deſcribe a curve which ſhall return into itſelf. A mathematician may make this appear plauſible upon paper; but it is no practical truth, be the ſpeculation ever ſo pleaſing.

IT is neceſſary then to call in the aſſiſtance of ſome medium, as an agent, to renew this projectile force as faſt as it decays. Philoſophers might perhaps find their labour well repaid, if they would enquire whether any ſuch is to be met with: and they will pardon me, if I tell them, ſuch an enquiry can be no diſgrace to them; for *Galilæo* himſelf, the greateſt geometrician of his time, to whom the preſent age is indebted for a conſiderable part of its knowlege, was perſuaded the ſun might occaſion the motion of the planets in a mechanical way *.

IT ſhould alſo be conſidered, now we are upon this ſubject, that the motion of the planets is not perfectly circular, but *elliptical*. At ſome times they are driven farther off from the ſun toward the higher *apſis* of their orbits: at other times they approach nearer to him, as they tend toward the lower. To this it is wholly owing, that the earth is nearly eight days longer in paſſing from the vernal equinox to the autumnal, than from the autumnal to the vernal. If they are carried off by a projectile force, and brought nearer by an attractive, neither the one nor the other can continue in the ſame ſtate through any one of their revolutions, or to ſpeak more ſtrictly, through any two points in one half of their ellipſes. How are we to account for it, that the projectile force, when once over-ballanced by the attractive, does not ſo far decay, as to let the planet draw up in a *ſpiral*, till it falls into the centre? When the attraction of gravity is accelerating the motion of a planet or comet, and cauſing it to approach nearer to the ſun with great rapidity, it brings it down to a certain point only, but never below it: for when it has reached this point it riſes again immediately, which, without ſuppoſing ſome *new force* to act upon it, is altogether impoſſible. In the theory of projectiles in *vacuo*, there is no caſe parallel to this, or in any degree like to it: for let a planet be projected from the higher apſis of its orbit, with any force leſs than infinite, and its deſcents below the tangent, according to the known laws of projection, will be as the *ſquares of the times* from the beginning of its fall, till it attains a point either of relative or abſolute reſt.

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* See his letter to the grand-dutcheſs of *Tuſcany*. p. 57.

As to the motion of the moon in particular, there are, upon this ſame plan of gravity and projection, ſome certain circumſtances attending every conjunction, which are known to contradict the firſt principles of mechanics: but theſe, if inſiſted upon at large, would carry me out far beyond my deſign. An author I have already ſpoken of, who, if I comprehend him, is a moſt zealous aſſertor of gravity and a vacuum, has to my great ſurprize repreſented this and ſome other things which have frequently engaged my attention, in a method ſo plain and unanſwerable, as to render my labours unneceſſary. To his book therefore I beg leave to refer thoſe who require any farther ſatisfaction [*]. In our *concluſions*, I muſt confeſs, we differ very widely. The end I have propoſed in mentioning theſe things, is to ſhew the neceſſity of a material agency in the heavens, ſubordinate to the divine power: whereas it is his deſign to ſhew from the ſame premiſes, that God himſelf is the agent immediately. Which of theſe two is the more rational inference, I leave to be determined by the impartial judgment of others, after they have weighed the following reflexion — That if the extravagances, which would ariſe in the planetary motions from attraction and projection, are any way to be corrected and regulated, it muſt be done either *phyſically*, by the inſtrumentality of ſome material agent properly adapted; or *ſupernaturally*, by ſome immediate influence of divine power. If *phyſically*, then the motions which are *corrected* by a phyſical agent, may as well be *cauſed* in the ſame manner. If *ſupernaturally*, that will give every pretender to philoſophy a liberty of propoſing what powers he pleaſes, and all of them equally good, if they are to be mended at every turn by a miracle. Indeed, it will be no better than a jeſt, to propoſe any powers at all; and Sir *Iſaac*'s firſt *law* which is called a law of *nature*, and from which he hath attempted to deduce ſo many things in a *natural* way, will have neither meaning nor uſe in philoſophy, if this author's doctrine be admitted. A miraculous interpoſition therefore is never to be confounded with the eſtabliſhed order of natural things, if we would underſtand what nature is, or what a miracle is. Such a method of philoſophizing will give a ſanction to every ridiculous hypotheſis, that doth not quite come up to an impoſſibility: and I can ſee no good reaſon, why the *vortices* of *Des-Cartes* may not claim the benefit of a miracle to ſupply their defects, as well as this more modern, but equally fictitious, compoſition of *central forces*. Upon what principle was it that Sir *Iſaac Newton* ſaid — "Hypotheſis vorticum multis premitur difficultati- "bus?" certainly not upon the principle of this author; for at that rate, there can be no ſuch thing as a *difficulty*. The ſame omnipotent hand, which is ſuppoſed to ſave a planet from ruin, by driving it farther from, or drawing it nearer to the centre, as occaſion requires, may as eaſily conduct a comet thro' the whirling *vortices* of *Des-Cartes*, or even the ſolid chryſtalline orbs of *Ariſtotle*. This is the common refuge of men who have nothing elſe to ſay; and it was the excuſe advanced by *Ptolemy*, in behalf of his perplexed ſcheme of *excentrics* and *epicycles* — No man was to call in queſtion the truth of his aſtronomical theories, becauſe the *immortal Gods* could eaſily find a remedy for every difficulty; could remove all impediments, and make a way in the heavens for the motion of every orb, though their courſes might ſeem to be inconſiſtent with one another *. When the philoſopher aſſures us, *power* is a divine attribute, we can readily believe him: but if he is above ſearching after what the divine *wiſdom* hath thought proper to eſtabliſh in the world, and takes refuge under the abſtract notion of an unlimited power, before there is a neceſſity for it, and even while experience is againſt him, he betrays the inſufficiency of his own ſpeculations; and muſt convince mankind, either that the whole of nature is an uſeleſs and inexplicable myſtery, or that he ought to ſet out afreſh upon more conſiſtent principles.

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[*] See *appendix* to an enquiry on the nature of the human ſoul. ſect. 8.

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* Nemo vero difficiles cenſeat has quas ſupponimus circulorum implicationes &c. *Kepler.* epit. aſtron. p. 502.

END OF THE SECOND BOOK.

BOOK III.

Of a vacuum *in the heavens, and between the parts of bodies: with an experimental enquiry into the phyſical cauſes of* coheſion *and* repulſion.

CHAP. I.

Some poſitive proofs, that a medium, *different from the rays of light, is preſent in the heavens; with an anſwer to a common objection from ſome experiments with the* barometer.

THE beſt-reputed argument hitherto made uſe of to prove a vacuum, has been derived from a ſuppoſed *neceſſity* for it, that the bodies in the heavens may be *unreſiſted* in their motions. But we have been taught by ſome undeniable examples, that motion may continue unreſiſted in a reſiſting medium, if that medium be the *cauſe* of the motion: ſo that the whole doctrine of reſiſtance is of no uſe, unleſs the queſtion be firſt granted, that the motion of the planets is not owing to any *material cauſe*; that is, unleſs the very thing, which ought to be proved, be taken for granted. If the matter of the heavens is not employed as a phyſical cauſe, then indeed it will be an obſtruction, and ſerve only to interrupt and retard motion. If the air *behind* the ſails of a ſhip were not inſtrumental in driving the ſhip forward; the air *before* the ſails would ſerve only to ſtop the courſe of it. If a motion were communicated by the hand to the lamp-machine deſcribed in the former part of this treatiſe*, and it were made to turn upon its centre when the lights are extinct; the air which ſurrounds the vanes would reſiſt their progreſs, and the machine would not make near ſo many revolutions as if it had been included in a vacuum. But if the lights are burning, the caſe will be entirely altered, and the air will now conſerve that motion, which a while ago it deſtroyed. This diſtinction of caſes is ever to be remembered in all our phyſical reaſonings: the moſt ingenious and able philoſophers, by not attending to it, have fallen into palpable miſtakes; and it is greatly to be lamented, that the fact here mentioned has found no place in the received philoſophy, though it calls itſelf *experimental:* nay the impoſſibility of ſuch a thing has been formally demonſtrated in a geometrical way.

A vacuum therefore is no *neceſſary* principle. We ſhould rather conclude, if we are willing to be guided by analogy and experience, that as motion continues in the heavens, ſome active medium muſt be preſent for the conſervation of it. Let us enquire then, whether the exiſtence of ſuch a medium in the heavens, excluſive of the rays of light, will admit of any poſitive proof; and whether we can obviate a material objection which hath been raiſed againſt it: after which we will leave the celeſtial vacuum, and examine the nature of ſome leſſer vacuums.

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* See page 44.

So long as the philoſophy of *Ariſtotle* prevailed, *poſitive levity*, differing only in ſpecie from gravity, was believed to be a quality of ſome natural bodies: but the members of the *Florentine* academy ſhewed the falſehood of it by ſome judicious experiments; and it is now determined, that if one body or fluid *tends upwards*, it is only becauſe another of greater denſity *tends downward*, and takes the place of it. Thus if air and water be mixt together, both of them gravitate (as we commonly ſpeak) toward the centre of the earth; but the water, having the greater denſity, will gain the loweſt place, and in ſo doing, cauſe the air to *aſcend* with a velocity proportional to their difference. What is here ſaid of air and water, may be applied to ſmoke and air; the caſes being alike in all reſpects. This reaſoning, if found to be juſt in every inſtance where we have an opportunity of making the trial, muſt be admitted on all other occaſions of the ſame nature, though we have not the like opportunity; according to the known rule — *Effectuum naturalium ejuſdem generis eædem ſunt cauſæ* — "Natural effects of the ſame kind muſt be imputed to the ſame "cauſes." If this liberty of arguing from a ſimilarity of effects be once denied us, all *experimental* philoſophy will be in a manner uſeleſs.

I muſt be permitted then, in virtue of this rule, to argue from the aſcent of bodies near the earth's ſurface, to the like effect, when it happens at any diſtance from us in the heavens; as for example, near the head of a comet; from which an immenſe train of vapour is obſerved to fly off, or rather to *riſe upwards* into the regions oppoſite to the ſun; for thus we ſhould expreſs ourſelves, if we were placed upon the ſurface of it.

Now let the obſervation concerning ſmoke and air be here applied; and it will be more than probable, that ſome fluid in the heavens, of a denſity much greater than theſe vapours, muſt be tending *downwards* to the ſun, that they may be carried off in a contrary direction, according to the law above-mentioned. For the ſame reaſon, this fluid ought to be preſent in all the ſpaces, through which the tail of a comet is known to extend itſelf, which is ſometimes to an almoſt incredible diſtance: otherwiſe the principle of a poſitive levity, or ſomething equally unaccountable, muſt be admitted as a conſequence. An imaginary atmoſphere, ſurrounding the nucleus of the comet, will give us but little aid; the caſe not being paralleled (I mean with reſpect to the comet and its own atmoſphere) by any thing that happens within the atmoſphere of this earth; in which ſmoke and vapour will riſe up on every ſide indifferently, as well at noonday as at midnight; and will go, either toward the ſun, or from it. But the tail of a comet, *after* it has paſſed its perihelion, as well as *before*, is turned away *from* the ſun; at which time, as we ſhould naturally expect, ſome more looſe and detached particles might be left behind by the reſiſtance of ſome ætherial medium, and carried toward the ſun by their gravity: the contrary to which hath always been obſerved to happen: ſo that we muſt impute the whole effect to an univerſally extended atmoſphere, not of the *comet itſelf*, but of the *ſun*.

This phœnomenon, though very diſtant and inacceſſible, is nevertheleſs ſo clear in itſelf, and its application is ſo obvious, that it cannot eaſily be miſunderſtood. Thoſe who believe the heavens to be nothing but an immenſe vacuum, are bound in reaſon, I think, to give us ſuch an account of it, as ſhall be ſatisfactory in itſelf and conſiſtent with their own principle. If no ſuch account can be given, there will be a neceſſity for introducing ſome fluid into the heavens beſide the rays of light; and when we ſpeak of ſuch a thing, we ſhall do it with reaſon, with obſervation, and I may add with Sir *Iſaac Newton* alſo, on our ſide; who ſeems to have conſidered this matter attentively, and has granted all we can deſire of him. His words are theſe — "For as "in our *air*, the ſmoke of any body that is ſet on fire goes "upwards, and that perpendicularly if the body be at reſt, "or obliquely if it be moved ſideway: *ſo in the heavens*, "where bodies gravitate toward the ſun, ſmoke and vapours "ought to aſcend from the ſun, and go off to the higher "regions*." This whole paſſage being very important, I muſt beg leave to ſubjoin a few ſhort remarks upon the ſeveral portions of it.

"For as in our air, the ſmoke of any body that is ſet on "fire goes upwards" &c. The reaſon already aſſigned for this need not be repeated. Should it be diſputed, experiment will make it good. For let any burning matter be placed under a pneumatic receiver, not exhauſted of its air; the ſmoke will riſe up perpendicularly, and with a conſiderable velocity: but when the air is exhauſted, the ſmoke, inſtead of riſing up as before, will either ſink down like water, or hover as an atmoſphere about the ignited body. It follows from this experiment, and many others, that a fluid which is light and rare, cannot aſcend by any innate quality of its own; but muſt be impelled, or forced up, by another fluid more denſe and weighty.

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* Etenim ut in aere noſtro, fumus corporis cujuſvis petit ſuperiora, idque perpendiculariter ſi corpus quieſcat, vel obliquè ſi corpus moveatur in latus: ita in cœlis, ubi corpora gravitant in ſolem, fumi & vapores aſcendere debent a ſole, & ſuperiora vel recta petere. *Princip.* p. 469.

This aſcent of ſmoke &c. will be "perpendicular if "the body be at reſt, or oblique if it be moved ſideway." Thus the flame of a candle will have a perpendicular direction if it is at reſt; but if it is carried forward, and meets with a reſiſtance from the air, the flame will then have an oblique direction, and be more bright and better defined at the edge where the reſiſtance is made, than at the other. Aſtronomers tell us, the like has been obſerved in the tail of a comet. But we are coming now to the application.

"So in the heavens, where bodies gravitate toward the "ſun, ſmoke and vapours ought to aſcend from the ſun." As on the earth, to which bodies gravitate, ſmoke aſcends through air, becauſe the air forces it up by gravitating *more* than the ſmoke; ſo in the heavens, which according to this ſame author are *empty* of *air* and of all *ſenſible matter*, vapours ought to aſcend from the ſun. How can theſe things ſtand together? Would it not be better totally to diſbelieve a *vacuum* in the heavens, than to be thus diſtreſſed with contradictions? Sir *Iſaac* himſelf, upon this occaſion at leaſt, ſeems to have thought ſo; therefore he adds again very expreſſly in another place — "Smoke aſcends in a chimney "by the impulſe of the air in which it floats. This air, "being rarefied by heat, riſes up, becauſe its ſpecific gravity "is diminiſhed, and carries off the ſmoke entangled with it. "Why may not the tail of a comet aſcend from the ſun "after the ſame manner*?" There can be no objection to this, but that the heavens will not then be *empty*. Vapours cannot aſcend from the ſun *after the ſame manner* as ſmoke

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[*] Aſcendit fumus in camino impulſu aeris cui innatat. Aer ille, per calorem rarefactus, aſcendit ob diminutam ſuam ſpecificam gravitatem, & fumum implicatum rapit ſecum. Quidni cauda cometæ ad eundem modum aſcenderit a ſole! *Ibid.* p. 472.

riſes in a chimney, if in the ſpaces through which they aſcend, there be neither *impulſe*, nor *air*, nor any *ſenſible matter*.

If we agree here with Sir *Iſaac Newton*, and determine theſe caſes to be parallel, the concluſion will be unexceptionable; that as the *air*, in which ſmoke aſcends, is no *vacuum*; ſo neither are the ſpaces through which vapours aſcend from a comet.

And to go a ſtep farther, the reaſoning which hath been applied to theſe vapours, may be applied with the ſame propriety to the *rays of the ſun*; for as the motion of both is in the ſame direction, no difference between them, in any other reſpect, will be material. Light then muſt be propagated from the ſun, either by an innate *levity*, in a manner not analogous to any thing we are acquainted with; to ſuppoſe which is to give up the whole cauſe; or by the preſſure of ſome denſer medium going downward to the ſun. It is true, Sir *Iſaac* in his treatiſe on optics, hath rejected all ſuch mediums in a peremptory ſtrain: but if his theory of reſiſtance hath failed, we may be able to ſurmount all leſſer difficulties. Indeed I know but of one that deſerves to be conſidered. Upon a firſt view of it, it threatens us with ſome trouble, and will put us upon an exact enquiry.

It hath been judged from ſome experiments with the barometer, that we are now able to calculate the height of the air which ſurrounds this globe, and to fix very nearly upon that diſtance, beyond which, if there is any matter at all, it muſt be *perexigua* "exceedingly little," *aüra longè tenuiſſima* "an air thin beyond expreſſion." The weight of the atmoſphere at a middle ſtate, is equal to 29 ½ inches of mercury, at the ſurface of the ſea. If we aſcend to the height of 800 feet, it will ſink an inch lower; at double that

height,

height, it will be lower ſtill; and ſo on, as far as we can convey ourſelves to make the trial. Hence it is preſumed there is a certain diſtance above the earth's ſurface, at which the mercury in the barometer would fall to a level with its ciſtern; and conſequently the heavens, at that diſtance, muſt be empty of air, at leaſt of ſuch air as is attended with any ſenſible preſſure upon the ſurface of bodies.

FROM all that has hitherto been done upon this ſubject, it does not appear that a theory can be laid down, ſo as to determine the ſtations of the barometer with accuracy, when the elevations above the ſurface of the earth are very great. When they are but moderate, this method of meaſuring altitudes is very convenient, and comes nearer to the truth than a quadrant and a trigonometrical operation would do. But, I apprehend, the higher we go, the greater will be the error. Between Drs. *Halley* and *Scheuchzer* there is a difference of near 800 feet in 5000. The former of theſe having erected a theory *, finds an elevation of 5000 feet requiſite to reduce the barometer to 24. 93 inches; while the latter, who purſued his enquiries with great diligence, and every imaginable advantage, upon the *alps* of *Switzerland*, reduces the barometer to the ſame ſtation, with an elevation of 4241 *Engliſh* feet †. There are other calculations of *Mariotte* and *Caſſini*, which differ widely from each other.

BUT to come to the point. That there really is any imaginable elevation above the ſurface of the earth, at which the barometer would have no altitude, and the air no perceptible denſity, cannot be inferred from any barometrical experiments; all of them having been taken in that *lower region*, within which the air is no other than a menſtruum, ſaturated to an high degree with heterogeneous particles of a groſſer ſubſtance, and more eſpecially with the particles of *water*. The clouds indeed, at leaſt in this country, are very rarely higher than three quarters of a mile, even in the moſt ſerene weather, when the barometer is high; and ſometimes they do not exceed ſeven or eight hundred yards, as I have found by obſerving their altitude at different ſeaſons: but we ſhall err greatly if we imagine the watry vapours to be carried no higher than to the path of theſe clouds; for mountains, above a mile in height, being covered with *ſnow*, muſt be within the region of vapours. When Mr. *Ray* as he tells us himſelf, was croſſing the higheſt ridge of the alps in the country of the *Griſons*, it *ſnowed* very faſt during his whole paſſage, and "the clouds ſeemed "to be as far above his head as they do here in *England*[*]." At the top of the *Pico Teneriffe*, as Dr. *Sprat* has delivered the account in his admirable *hiſtory of the royal ſociety*, "a "perſon found himſelf all wet, and perceived it to come "from a perpetual trickling of water from the rocks above "him." Another account, in the *philoſophical tranſactions*, ſpeaks of a *dew* falling there, at the very ſummit, ſo copious as to wet the clothes of the company; and it laſted till ſun riſing[†]. *Varenius* ſuppoſes, after all the proper deductions for refraction &c. that the top of this mountain is viſible at the diſtance of two degrees and an half upon the meridian; whence the height of it will be three *Engliſh* miles and three quarters. Whether this calculation be exactly right or not, though I think the real height cannot be very far ſhort of it, certain it is, as *Varenius* hath obſerved,

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* For a particular account of it, ſee *Philoſ.* Tranſ. No. 181. p. 104.

† See *Ibid.* No. 406. p. 577.

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[*] Three diſcourſes. p. 104.

[†] N. 345. p. 317.

quòd non ultrà mediam regionem aëris protendatur * — "that "it is not extended beyond the middle region of the air." How much higher the watry vapours may aſcend, it will be hard to ſay; but ſo high they certainly do aſcend.

From a very common experiment with the air-pump, water appears to be at all times ſuſpended in the element of air. After a ſtroke or two of the pump, the remaining air within a receiver, being rendered lighter, never fails to let fall a cloud of vapours. Dry ſalt of tartar incloſed in a glaſs well ſtopt, will imbibe ſo much water as to make up the largeſt part of the weight of the included air: which led Dr. *Boerhaave* to conjecture, that pure air, in its elaſtic ſtate, does not gravitate at all †. I have ſometimes admitted air into an exhauſted veſſel, fitted for the purpoſe, firſt in a dry room with a fire in it, then upon a damp ſtair-caſe, and have found the latter to be ſomething heavier, by hanging the veſſel to the arm of a ballance.

All theſe facts ſhould be taken into the account, and ſome allowance be made for them in our modern atmoſpherical theories. They will not prove perhaps that pure air is abſolutely without gravity, which is what I cannot believe; but they will prove very well what I intended to ſhew, that experiments made within the lower regions of the air, are by no means concluſive when applied to the higher, into which no barometer will ever be tranſported, unleſs Dr. *Wilkins*'s ſcheme for flying up to the moon ſhall hereafter be put in execution.

To this admixture of vapours, might poſſibly be owing thoſe unexpected irregularities in the barometer, which almoſt threw the induſtrious *Scheuchzer* into deſpair. During his peregrination upon the alps, the mercurial column was ſometimes *higher* upon thoſe mountains, than it was obſerved to ſtand on the ſame day, and with the ſame temperature, at *Zurich*; which is directly oppoſite to the received rule [*]. He imputes this to the greater *purity* and *elaſticity* of the air in the *alpine regions*. Theſe irregularities however drew from him the following confeſſion, for which he is much to be honoured — "I pretend not to lay down the truth, as "if it were fully cleared of every doubt; for after all my "enquiries, it ſeems to be ſtill concealed under a cloud [†]:" and indeed ſo it is; if, by *the truth*, we underſtand that theory of the atmoſphere, which terminates in a *vacuum*.

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* Geograph. lib. 1. cap. 9 & 10.

† See his *method of chemiſtry* by Dr. *Shaw*. vol. I. p. 400. and 419.

But after all, one poſitive proof with regard to the higher regions, would be worth all that can be ſaid in anſwer to experiments on account of their not having been actually taken within them. Such a proof is to be met with, ſo plain and ſtriking, that I may venture to reſt this whole affair upon the ſtrength of it.

According to the preſent ſtate of experimental philoſophy, air is allowed to be the vehicle of ſound: and whether it be the proper pabulum of fire or not, it is, generally ſpeaking, neceſſary to the kindling of fire, and to the preſervation of it. When the receiver of an air-pump is well exhauſted, a ſmall bell cannot be heard to tranſmit any of its ſound, if it be prevented, (as it eaſily may) from communicating its tremors to the external air, through the ſolid matter of the machine. Gunpowder will not take fire in ſuch a ſpace; and a candle will expire, before half the air can be extracted. Theſe things being premiſed, I proceed to my narrative.

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[*] *Itinera Alpina.* p. 15. Itin. ſecund. —— "*In diverſorio Ragazienſi* &c.

[†] Imo nec prætendo veritatem omnibus dubiis plenè liberatam adhuc dum ſiſtere, quæ operta nubium involucris mihi ipſi videtur. *Ibid.* p. 9.

In the year 1719, a *meteor*, very far exceeding the moon in luſtre, and nearly as large in appearance, was ſeen over all the parts of *Great Britain*, *Ireland*, and *Holland*, the nearer parts of *Germany*, *France* and *Spain*, at one and the ſame inſtant of time. Its apparent altitudes were accidentally obſerved by ſkilful perſons at *London*, *Oxford*, and *Worceſter*, and near enough to the truth, by the aſſiſtance of the ſtars. The horizontal diſtances of theſe places being known, together with the ſemidiameter of the earth, and the different angles under which the phœnomenon appeared to diſtant ſpectators at the ſame time, its abſolute height above the earth's ſurface may thence be found to a degree of certainty, which will not be diſputed by thoſe who are acquainted with the rules of trigonometry. From theſe data, it appears to have been about 70 ſtatute miles high. Over *Devonſhire*, *Cornwall*, and the neighbouring counties, an *exploſion* was heard, equal to a report from a broadſide of the heavieſt cannon at ſome diſtance, which was ſoon followed by a rattling noiſe, as if many ſmall arms had been promiſcuouſly diſcharged. This ſound was attended with an uncommon tremor of the air, and every where in thoſe counties very ſenſibly ſhook the glaſs windows and doors of the houſes, and even the houſes themſelves, beyond the uſual effects of cannon when fired near at hand.

The account of this meteor was drawn up at large by Dr. *Halley*, from the intelligence received upon the occaſion by the *royal ſociety**. The concluſion from the whole is plain enough: therefore inſtead of making any remarks of my own upon it, I ſhall add the more weighty and inge-

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* *Phil. Tranſact.* No. 360. p. 978. This account is preceded by ſeveral others, leading to the ſame concluſion, in the 2d vol. of Mr. *Motte*'s continuation of *Lowthorp*'s abridgment p. 138.

PLATE III.

page 129.

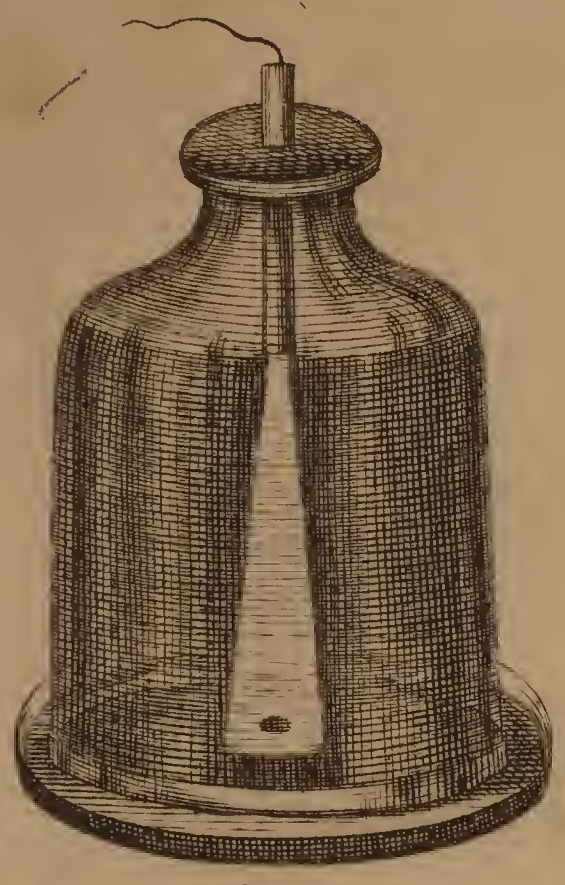

Fig. 1.

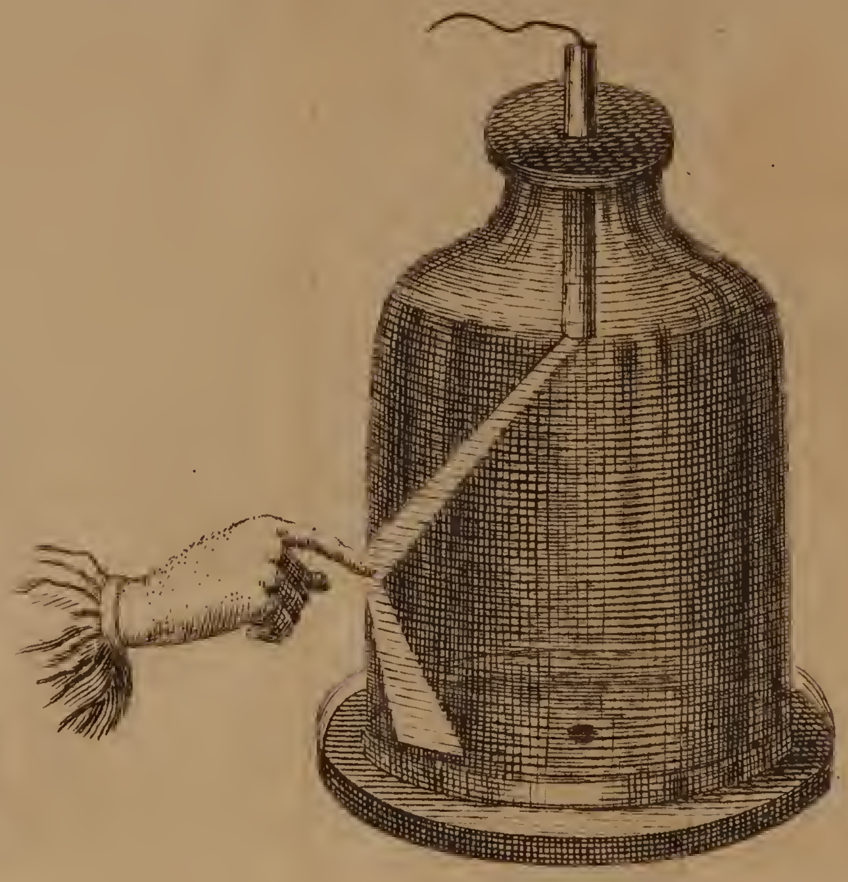

Fig. 2.

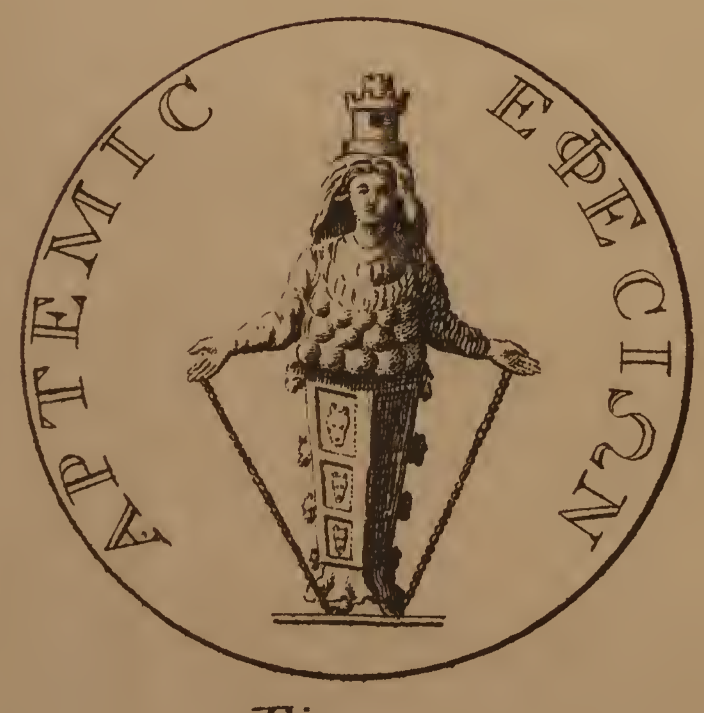

Fig. 3.

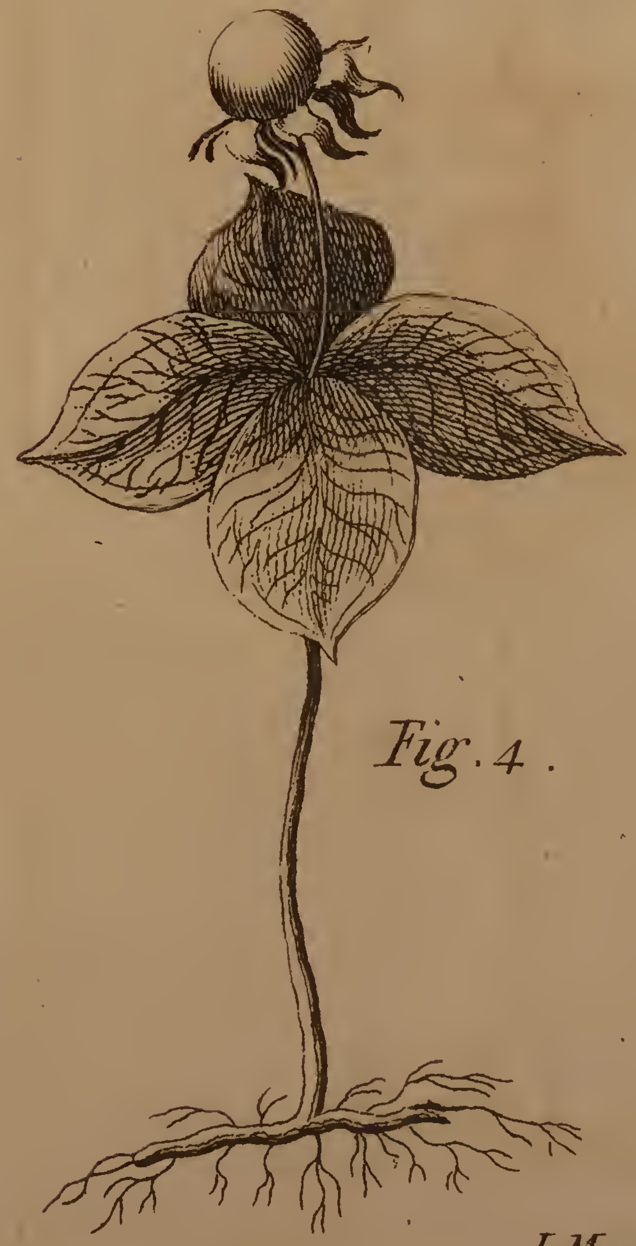

Fig. 4.

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nuous reflexion of the celebrated author himſelf — "what "may be ſaid to the propagation of ſound through a me- "dium, according to the received theory of the air, above "300,000 times rarer than what we breathe, and next to a "vacuum, *I muſt confeſs, I know not.*"

CHAP. II.

Some poſitive proofs, that a medium, *endued with* very great force, *is preſent between the* interſtices *of groſſer bodies, and in other ſpaces uſually called* vacuums.

LEAVING then the celeſtial vacuum to be proved by ſome future arguments, more unexceptionable than any hitherto advanced; we muſt deſcend to examine the ſtate of ſome leſſer vacuums; whether made by the help of art and machinery, or left by nature itſelf in the interſticial vacuities of ſolid or fluid bodies. That none of theſe can with any philoſophical ſtrictneſs be termed *vacuums*, though we are ſometimes obliged, for the ſake of diſtinction, to call them ſuch in common diſcourſe, will be clear from the following conſiderations.

SUPPOSE a receiver (plate III. fig. 1.) to be placed upon an air-pump, and well evacuated. Into the plate at the top of it, a cylinder of wood or metal is inſerted, and made to communicate with an electrical machine in motion. If the room be dark, a ſtream of fire will be ſeen to iſſue from the lower end of the electriſed cylinder, and go ſtrait down to the plate at the bottom. But if any perſon applies his finger to the ſide of the glaſs, as in fig. 11. the ſtream will receive a new direction, and be bent to that part of the glaſs to which the finger is applied. The better the receiver is cleared of its air, the better this effect will be found to anſwer.

In the opinion of ſome ſpectators, prepoſſeſſed with the notion of *qualities*, this might paſs for a good proof, that the finger *attracts* the fire. Nevertheleſs, that ſome ſubtil medium, though inviſible, is preſent to divert the courſe of the fire, may thus be proved. It may be previouſly learnt from ſome other experiments, that the electrical fluid is acted upon according to mechanical laws. Thus, for example, the reſiſtance of the air being much greater upon the ſpherical ſurface of a large cannon bullet, than upon the point of an iron rod; the fire will be confined within the bullet, while it eſcapes with eaſe from the point of the rod. Where the reſiſtance of the air is removed from one part of a body while it acts upon another, the electrical ſtream will go off at that part, from which the reſiſtance is removed, without any regard to the figure of the body. In ſhort, it is found from theſe plain and intelligible caſes, that this fluid *acts* as it happens to be *acted upon*, and is *impelled* to that ſide, where it meets with the leaſt degree of preſſure. As the medium within the pores of ſolid bodies, is known to reſiſt it leſs than any other we are acquainted with, for this reaſon it is driven toward the finger. But then if there be no medium within the glaſs, the ſtream will be equally affected on every ſide; or, which is the ſame thing, not preſſed at all on any ſide, and ought to go directly down to the plate, as before in fig. 1; for an abſolute vacuum, which is *nothing*,

thing, cannot be able to impel and divert the courſe of it. If it is *drawn* to the finger by an unmechanical attractive quality; then I am to conclude, againſt all reaſon, that this fluid is unlike to itſelf; mechanical on ſome occaſions, and unmechanical on others. But we are under no neceſſity of falling into ſuch a contradiction. An agent capable of acting upon it by a mechanical impulſe or preſſure, is preſent within the receiver; and if the reader is not convinced of this, by what I have already ſaid (as I can hardly expect he will, if theſe things are new to him) what I am going to add will give ſome farther ſatisfaction.

IF the electrical æther be *elaſtic*, as it is generally imagined to be, how can it paſs in an uninterrupted column through an exhauſted receiver, as it does in fig. 1? A column of air, moved ſwiftly thro' the orifice of a ſmall pipe, will go forward a conſiderable way, if it moves through other air which is a counterballance to it on every ſide: but if ſuch a column of air enters a vacuum, what we call its *elaſticity* occaſions it to be diſſipated in a moment, and *equably diffuſed* throughout the whole exhauſted ſpace. As the like does not happen to the electric fire, it is either not elaſtic, which cannot be ſuppoſed, or the ſtream is counterballanced on every ſide by a medium of its own kind, which prevents its diſſipation. When it enters a medium rarer (that is, of more ſubtil parts) than itſelf, as within the pores of cloſe and denſe bodies, it is then equably diffuſed, like the column of air when it enters the exhauſted receiver. When it meets with a medium denſer than itſelf, as within the more open pores of glaſs, amber, roſin &c. it will not enter without ſome violence; as air is with difficulty forced into and confined under water. From theſe few and obvious principles, naturally ſuggeſted by a ſimilarity of circumſtances in the air, a fluid more intelligible than the ſubtil æther with which we have had but a ſhort acquaintance, the moſt difficult appearances in electricity may be accounted for.

The preſence of a medium within an exhauſted receiver doth alſo follow, becauſe there is no ſpace, how perfectly ſoever it may be evacuated of common air, wherein fire will not riſe perpendicularly upwards from a red hot iron, and heat a receiver at the top more than at the ſides, though they are neareſt to the fire. The fumes of gunpowder will be carried up together with the fire, and in the dark will exhibit a beautiful appearance, verymuch reſembling that of an *aurora borealis*. I made this experiment with the mercurial gauge at 29 inches; and it would ſucceed, as we have no reaſon to doubt, could it be brought to the full height of a good barometer. From this forcible aſcent of the fire and fumes, there muſt be other matter in what we call the *empty* ſpace, by the *preſſure* of which the fire is driven upward. Thus we argue in all parallel caſes; and if this be excepted, we muſt have recourſe to an *innate levity*, which has long been exploded, and juſtly enough *. Dr. *Halley* indeed does allow of a *tendency contrary to gravity*, and an *innate levity*; but I apprehend we are to take theſe for nothing more than unwary expreſſions.

The ſpace at the top of a barometrical tube, if the mercury be pure, and the glaſs clean and dry, is a much better vacuum than that of a pneumatic receiver. But the more effectually it is cleared of air, the better opportunity we have of ſhewing it to be filled with other matter. For let the tube be inclined a little from the perpendicular, till the mercury reaches to the crown of it; then if it be ſuddenly reſtored to its firſt poſition, and the room be well darkened, or the experiment performed in the night, a pale light will be ſeen to occupy the ſpace, as faſt as it is deſerted by the mercury; and this light will return, as it were by flaſhes, ſo long as the mercury continues to vibrate in the tube.

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* See page 119 &c.

It was the faſhion, ſome years ago, to give this barometrical light the name of a *mercurial phoſphorus*; as if it were an anomalous production from the mercury: whereas this light and the electrical æther, as ſome farther enquiries have taught us, are one and the ſame fluid; and the mercury is not neceſſary to the effect. If the glaſs of the tube be very thin, let the top of it be made to touch the *conductor* of an electrical machine, and the light will give the ſame appearance as if the tube had been agitated. After this, empty the tube of its mercury, and add ſome contrivance for exhauſting it by the air-pump; then let it be applied to the conductor as before, and ſtill you will have the ſame appearance of light.

When a baſon of mercury is agitated *in vacuo*, large flaſhes of light will ſeem to be reflected from the ſurface of it. The mercury does not *create* this light, but only *renders viſible* a fluid already preſent in the exhauſted ſpace. For the matter of light may, and actually does, exiſt, where the ſenſe of ſeeing will give us no information of it. A piece of ſolid *phoſphorus*, immerſed in a phial of water, is in all appearance as cold and opaque as a lump of hard wax: but as ſoon as it is taken out and expoſed to the air, it ſmokes and ſhines, and if excited by a ſmart friction will inſtantly break out into an actual flame. This ſubſtance ſeems to be a mere creature of the fire, like fixt alcaline ſalts and many other productions of chemiſtry; and in its preparation abſorbs a large portion of that element into its pores; whence *Lemery*, with great propriety, calls it a *fire-ſponge*. So long as it remains under water, the impriſoned fire is kept in a quieſcent and inviſible ſtate; but if that preſſure be removed, it breaks out in a ſtream, flying off as fire does from any other ſort of fuel. It eſcapes more eaſily under an exhauſted receiver, than under the preſſure of the atmoſphere; for the ſame reaſon that a veſſel of hot water will grow cold, and part with its fire much ſooner under the like circumſtances; and the electrical phial, inſtead of being charged, will return back its fire, as faſt as it is infuſed.

But the nature of that ſubtil medium, which remains in every ſpace from which the groſſer air is exhauſted, may be farther underſtood, by enquiring into the force and condition of it within the *interſticial vacuities* of fluid or ſolid bodies. And as I ſhall take the liberty to ſpeak of electric and elementary fire, as if both were but one and the ſame thing, I muſt interrupt a little the order of my diſcourſe, by inſerting my reaſons for ſo doing; becauſe ſome ingenious men ſuſpect them to be different, and have attempted to render it probable by experiment, though their reaſoning is not ſo ſtrict as to deſerve any particular examination.

1. We call that *elementary* fire, which lights a candle, kindles ſpirits, and fires gunpowder. The electrical *æther* will do all theſe; and if it be different from elementary fire, then we have *two* material cauſes in nature, intended to produce the ſame effects, when either of theſe alone would have been ſufficient. And again; 2dly, if the electrical fire will have the effects of the elementary, it is equally true, that the elementary will have the effects of the electrical. The rays of the ſun will put amber and roſin into an attracting and repelling ſtate: the ſolar fluid being put into motion within the pores of theſe bodies, produces the ſame effects with the electrical; and in ſome particular ſubſtances a culi-

a culinary fire will do the like; though neither of them in any very conſiderable degree. 3. The light emitted by the attrition of a glaſs globe, and more eſpecially the ſpark of the electric exploſion, may be divided, by viewing it through a priſm, into the ſeven primordial colours, like the element that flows from the ſun, or the light emitted by a common fire; and the ſtreams of this matter, within an exhauſted globe of glaſs, aſſume all the colours of the rainbow; of which phœnomenon, ſome experiments mentioned in the optics of Sir *Iſaac Newton*, would afford a good ſolution. 4. When the ſolar light paſſes through a leaf of gold, held up between the eye and a window, only the *green-making* rays are tranſmitted; and it is remarkable, that the electrical ſpark, which iſſues from a body covered with leaf gold, is of the ſame colour, though ſomething more dilute. Upon the whole, if theſe fluids, which thus mutually and in all reſpects aſſume each others offices and properties, are not the ſame; experiment is a thing not to be depended upon, and the moſt obvious rules of philoſophizing, adopted and approved by all parties, are no better than ſpecious deceptions. That the electrical fluid is the ſame with that which is ſent from the ſun in the form of *light*, and gives *heat* to the atmoſphere, is ſtill farther evident from the production of *lightning*. After a ſerene day in the ſummer, when the air has been exceedingly heated, and the thermometer has ariſen ſuddenly to an unuſual height, we are generally ſure to be viſited with thunder and lightning: in which caſe, the matter *diſcharged* from the air in the form of lightning, is undoubtedly the ſame with the matter that was *accumulated*, and from which the exceſs of *heat* proceeded. But the matter of lightning, and that in the electric exploſion, are now allowed on all hands to be the ſame. I have had the opportunity many times of obſerving this to be the conſequence, when *Fahrenheits* thermometer has mounted ſome degrees above 76: and it is a thing commonly known, that a courſe of hot weather in the ſummer terminates with a thunder ſtorm; after which the air returns to a more mild and temperate ſtate.

The elementary, ſolar, and electrical fire then, as we have every poſſible reaſon to conclude, are but one ſubſtance acting in ſeveral capacities. This matter, being lodged within the pores of all bodies, water and ice not excepted, will leave no room for a *vacuum*. The denſeſt of metals are penetrated by it with more eaſe than the air itſelf. The farther end of a column, of any imaginable length, will be affected by the ſame touch that gives motion to the nearer, and in the ſame moment of time. The ſame quantity of it that is received into a body, will come forth from it again preciſely; and where none can be driven off, none will be admitted; for if the *Leyden* phial be ſet on a plate of thick glaſs, ſo that the external current from the coating is ſtopt, it cannot be charged: and for the ſame reaſon, if when charged, it be ſet on glaſs, pitch, roſin, or any other *electric*, it will retain its charge the longer and *explode with the greater force* *.

These things being conſidered, the element of *fire* appears to have ſuch a *continuity* of parts, and ſuch a degree of force in its motions, as would not have been believed without ſome ſenſible and immediate demonſtrations of it. Yet the ſame may be proved, without any help from the late diſcoveries in electricity. It is the ſame fluid that increaſes the bulk of bodies when they are heated, by entring forcibly into their pores and driving their conſtituent particles farther aſunder. The coheſion of braſs and iron is too weak to reſiſt the force of it; and unhappily for the philoſophic world, a very ſmall alteration of this kind is eaſily perceived in the rod of a pendulum. In boiling water, near one *thirtieth* part of its whole bulk, if we reckon only from the point of freezing, which carries us but a little way *, is occupied by fire; for to that degree its ſpecific gravity is diminiſhed, and conſequently its bulk is increaſed to the ſame degree. Air, under the like circumſtances, is increaſed by one *third* of its bulk. Now if a quantity of water, with a boiling heat, be ſuppoſed to occupy 30 cubic inches; when it is reduced to the loweſt degree of heat, with which it retains its fluidity, it will occupy but little more than 29. Thus its dimenſions will be different under all the various degrees of heat; and as the degrees of heat are always in a fluctuating ſtate, this liquid, in common with air and all bodies whatſoever, will undergo a perpetual oſcillation.

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* A young man, who ſerved me a year or two as an aſſiſtant, and paid no regard to the ſhock in the common way, was reſolved to try in private how this would anſwer; and unexpectedly received ſuch a ſtroke, from a phial capable of holding not more than ſix ounces of water, as laid him upon the floor, and he was not perfectly recovered of it in a month. Since this accident, being myſelf of a weaker frame, I have never dared to enquire too nicely into that matter. The ſame perſon was once ſtruck down in the field by a flaſh of lightning, which ſinged his coat, and the ſymptoms occaſioned by theſe two accidents, as he obſerved himſelf, agreed in all reſpects.

A queſtion naturally ariſes, how water, ſeeing its dimenſions are thus alternately extended and contracted, comes to be *incompreſſible?* Such the philoſophers of the *Florentine* academy determined it to be, by bruiſing and battering with an hammer an hollow ſphere of metal, filled with water and exactly cloſed; for the water, inſtead of being driven into a ſmaller compaſs by this external violence, was ſeen to ſweat like drops of dew thro' the pores even of gold itſelf [*]. So long as the water remains fluid, its parts cannot be in contact; becauſe if ſome of the *fire* be withdrawn, they will ſoon be reduced to a leſſer bulk, ſome force being externally applied upon this occaſion by nature itſelf, with which I hope the reader will be a little better acquainted before I have concluded this treatiſe. If more fire were introduced, by heating the water thus incloſed, it would either come forth through the pores of the metal, or burſt it all in pieces. Now as the water itſelf is *paſſive*, and may occaſionally be comprehended under greater or ſmaller dimenſions, it can be no other than the *agent within its vacuities* that reſiſts the compreſſing force; and its reſiſtance is ſo great, that no power of art or violence of machinery is able to overcome it; though nature itſelf hath a way of overcoming it in a moment.

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* Sir *Iſaac Newton* eſtimates, that water has *above* 40 *times more pores than parts.* See Opt. b. 2. p. 3. prop. 8.

As ſome doubt may yet remain, whether it be the element of fire that ſupplies the interſperſed vacuum (tho' in a tranſparent veſſel of boiling water, it may be ſeen to enter through its bottom in bubbles) or whether it be ſome immaterial *repulſive* force; I will try to explain myſelf a little farther upon this head, and add an experiment or two, which I am encouraged to hope may decide it.

If theſe ſpaces then are equably filled with *matter* of any kind, the quantity of this matter will be greater, where the denſity of the body containing it is leſſer; and *vice verſâ.* If we can prove it to be univerſally greater and leſſer as the rule requires, the concluſion will be undeniable, whether we are able or not to fix the exact proportion of it in every

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[†] The *Abbè Nollet* has a much more commodious way of performing this, mentioned in the 1ſt vol. of his *lectures*.

particular inſtance, which perhaps is impoſſible. If the rule can be obſerved to hold good generally and in groſs, it is the utmoſt we can expect or deſire.

Water and mercury then are fluids of very different denſities: and the water, according to the rule abovementioned, having the leſſer denſity, and of conſequence the greater number of pores, muſt receive a larger quantity of fire into them, than the mercury will receive into the pores of that, ſuppoſing them both to have equal bulks and equal degrees of heat. Let water and mercury therefore be taken in equal bulks: let the mercury be hot, obſerving the degree of its heat by a thermometer, and the water cold obſerving alſo the degree of that. Mix them ſuddenly; and having ſtirred them a little, ſo as to render the diſtribution of the heat equable throughout both the fluids; obſerve carefully the temperature of the whole by a thermometer. Then invert the experiment in all points: let the water have the ſame degree of heat that was in the former caſe given to the mercury; and the mercury have the degree of coldneſs before given to the water: mix them again; and the heat diſtributed through them both, will be *much greater now the water has the heat given to it, than when the mercury had it.* The latter of theſe, being the denſer, and having the ſtraighter pores, will take a ſmaller quantity of fire to give it an equal degree of heat: for if heat be nothing but the *effect of fire in motion*, and the degree of the heat be as the motion and denſity of the fire taken together, certainly it will move with the greater violence and be more compreſſed within the narrow paſſages of the mercury than in the wider ones of the water, from whence the whole effect is ſo eaſily deduced, that it needs no farther explanation. The thing will be found to anſwer in the ſame manner, but in a different degree, with ſpirit of wine and vinegar, or any other liquors, provided their denſities are ſo different, as to render the temperature of the mixtures ſenſibly different upon a thermometer.

All this doth neceſſarily imply a *transfuſion* of ſome *matter* or *element* from one of the bodies into the other. But upon the ſuppoſition, that their particles are expanded by an innate *repulſe*, or any *unſubſtantial* quality, theſe effects are altogether inexplicable and contradictory: for how can a quality be poured, like a liquor, from one veſſel into another; or move, like a river, with different degrees of force through channels of different breadths, as the fire plainly does?

Hence alſo the heat of ſolids and fluids cannot conſiſt in the vibratory motion of their own proper particles, but in the action and force of the fluid within their pores: it being againſt the laws of mechanics, that the particles of *water* which are fourteen times leſs in number and weight, ſhould communicate more motion to *mercury*, than the particles of an equal bulk of mercury will communicate to water.

There is indeed a difficulty, which ſome may look upon as a direct contradiction to what I have here advanced. For as a denſer fluid receives into it a ſmaller quantity of fire to give it an equal degree of heat, how does it happen, that when an iron is red hot, a denſer fluid will deprive it of its fire, and cool it more and ſooner than a rarer? This is indeed oppoſite to the rule already confirmed by experiment: yet it is aſſerted by Dr. *Boerhaave* in his *chemiſtry*; and I know it is a thing generally taken for granted, becauſe it is ſo agreeable to ſome opinions vulgarly entertained concerning fire and heat. I thought I could have depended upon the warineſs and caution, with which that great man uſually proceeded in all his enquiries, for the truth of this; and was endeavouring to reconcile it: but finding that to be impoſſible, I diſputed the truth of the fact, and reſolved to make the experiment; which accordingly I did, and it fully anſwered my expectation. I took about five pounds of mercury, the whole of my ſtock at that time, and having poured it into a crucible, obſerved the temperature of it by a thermometer of *Fahrenheit*'s ſcale, and perceived it to be — — — — — — 56°.

A ſmall cylinder of iron was laid in the fire for 10 minutes, till it was red hot; and after it had been quenched in the crucible, the mercury raiſed the thermometer to — — — — 69°.

Therefore the increaſe of heat in the *mercury* was — 13°.

Then I poured an equal bulk of *water* into the ſame crucible, and found the heat of it to be — 57°.

The iron was laid in the fire as before for 10 minutes, and being throughly quenched, the *water* raiſed the thermometer to — — — 63°.

Increaſe of heat in the water — — — 6°.

At a ſecond trial, in which the iron had a glowing heat, the numbers came out, in the *mercury*, 18°, in the *water* 9°.

At a third, when the iron had the beſt heat I could give it, the numbers were 20 ½ and 11 ½.

I repeated the ſame with a much larger cylinder of iron with a glowing heat; and having quenched it, till it had done hiſſing, in the *water*, the heat of which was 53°; the thermometer was raiſed to 150°. The mercury had a temperature of 57°; but when the ſame iron, heated as before, had been quenched in that, the thermometer was raiſed beyond the heat of *boiling water*, that is beyond 214°, and by the ſwiftneſs with which it moved, I judged it would have gone much beyond the compaſs of my inſtrument; therefore I could not determine the exact degree of heat in this caſe, without making a thermometer on purpoſe, which was not worth while. From the common reſult of all the other experiments, the ſame cylinder of iron, having equal degrees of heat, communicates *twice* as much heat to mercury, as to an equal bulk of water; ſo that the thermometer in this laſt trial would probaby have ariſen beyond 240°. Who would have believed that *fire* ſhould have an effect equal to 14, where it ought, according to the common eſtimation, and the *hypotheſis* of a *vacuum*, to have an effect equal only to $\frac{1}{2}$? [*] And that iron, when quenched in ſo denſe a fluid as mercury, ſhould remain ſo many degrees *hotter*, than when it is quenched in water?

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[*] The ſpecific gravity of mercury being about 14 times greater than that of water, the *quantity of matter* in a given ſpace, will be greater in the ſame proportion. Now if there be an *interſperſed vacuum* in theſe fluids; and if fire be nothing more than a certain vibratory motion communicated to their particles; then equal degrees of heat in any ignited body, (as here in the cylinder of iron,) ought, by the laws of mechanics, to communicate 14 *times as much motion* to a cubic inch of water, as to a cubic inch of mercury; whereas it doth really communicate only *half ſo much* to the lighter of theſe, as it doth to the heavier. Therefore the ſuperiority is on the wrong ſide, and in the ratio of 28 to 1, or 14 to $\frac{1}{2}$. But all this is natural enough, if fire is a fluid *per ſe*, filling the interſperſed vacuities of other matter, and raiſing a greater degree of heat, when it operates in a more confined ſpace.

Water and mercury, being fluids by nature ſimple, inſipid, and uninflammable, are, of all others in the world, the fitteſt for this experiment. If the ſame trial were made on oils, ſpirits, and other chemical liquors, which are inflammable, and impregnated with a *ſpirituous fire*, more eaſy to be agitated; many curious and unexpected varieties in the effect might occur, concerning which, it may be unſafe to affirm any thing without due examination.

THUS we are at length arrived to a concluſion, naturally ſuggeſted, and firmly enough eſtabliſhed, by a variety of facts; that the heavens are not empty even of the element of air; the contrary at leaſt hath never yet been proved, either from the doctrine of reſiſtance, the ſinking of a barometer, or any other method; and when the air is withdrawn or excluded, it leaves no *vacuum* behind it, but only reſigns its place to a medium of much greater power, whoſe extenſive, and I may ſay, univerſal agency, will afford us a moſt ſublime and intelligible proof of the divine wiſdom; and at the ſame time open to the curious a boundleſs field for entertaining and uſeful ſpeculations.

IF this be true, are not thoſe phyſical authors among the moderns, who have rejected, with a ſovereign contempt, all ſubtil mediums, as things fictitious, imaginary, and not worth ſearching after, hereby deprived of their greateſt ſubterfuge? Bodies, they ſay, are obſerved to adhere, to fly from, and approach one another in the void ſpace of an air-pump; and as theſe effects cannot be imputed to the air, they are not to be imputed (as they have too haſtily concluded) to any other *mechanical* agency; but to certain inexplicable virtues, which they call *coheſion* and *repulſion*. Theſe are the principles we are now, in the laſt place, to examine.

CHAP.

CHAP. III.

Of the phyſical cauſe of coheſion.

INSTEAD of ſetting out here with recounting all the minute phœnomena of capillary tubes, ſponges, drops of quickſilver &c. &c. which have all been enliſted as ſo many *undeniable proofs* of an *attraction of coheſion*; though Sir *Iſaac Newton* himſelf, more modeſt with all his knowlege, than ſome who have retailed his doctrines to us, propoſes none of theſe with any thing more than a ſuſpicion or a conjecture concerning them; and ſome of them, as I could eaſily ſhew, have not been fairly reported or ſufficiently inſpected; I deſire it may be conſidered — all the evidence of this ſort is *negative*; and owes its whole worth to an arbitrary ſuppoſition, that the air is the *only* mechanical agent in nature; and that merely through the want of another, we muſt have recourſe to immaterial qualities, exerted by the particles of the bodies themſelves; there being *nothing elſe* *, to which theſe effects can be aſcribed.

To all this, I oppoſe the following poſitive matter of fact, worth an hundred little critical experiments, concerning which much may be ſaid on both ſides, while very little is underſtood on either. It is this — Nature is provided with the element of *fire*, a material agent of ſufficient force and ſubtilty to overcome and undo the ſtrongeſt effects vulgarly aſcribed to coheſion. And as the deſign of our infinitely-wiſe and bountiful creator in appointing a material agency, was to build up rather than to deſtroy, to promote and preſerve an orderly diſpoſition in bodies, at leaſt as much or more than to cauſe their diſſolution; it is evident to reaſon, the ſame agent, acting with ſome difference of condition and circumſtances, muſt be ſufficient to do *both*. The air when ſtirred into a tempeſt will tear an oak up by the roots; but was this the ſole end of its creation? Does not the ſame air aſſiſt the oak and all other trees in their growth? and does it not nouriſh and preſerve many more than it deſtroys?

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* See Mr. *Rowning*'s account of the *capillary tube* in the *preface* to his ſyſtem of philoſophy.

Fire, another element, hath in like manner its different offices; and we may hope to gain ſome light into its more ſecret operations, if we argue by analogy from one of theſe to the other. That fire is the great catholic *diſſolvent* of nature, the chymiſts have all been ready enough to confeſs: that it can *unite* as well as ſeparate, ought not to be doubted; though it is what few will believe, unleſs they are poſſeſſed of patience and perſeverance enough to go through a cloſe enquiry. However, this matter is not ſo very difficult as they may apprehend.

Let us conſider this agent a while in the firſt and beſt known of its capacities, I mean as a diſſolvent. The particles of mercury, from the ſphericity of its drops, ſhould ſeem to be endued with a ſtrong attraction: yet theſe particles will ceaſe to have any coheſion, and be ſeparated into fumes by a degree of heat but little exceeding that of boiling water. The particles of water are alſo ſaid to be endued with the like virtue: yet the agency of fire will very ſoon relax their coheſion, as appears by a ſenſible diminution of their ſpecific gravity. The ſame fire acting with a ſtill greater degree of force, will at length totally diſſolve their union, and raiſe them aloft in ſteam or vapour. The ordinary heat of the ſun has a like effect on the waters of the ocean.

All other ſubſtances, as well ſolid as fluid, are ſubject to a ſeparation of their parts by the entrance of fire: the hardeſt of metals, how cloſely ſoever their parts may be connected, are eaſily diſſolved and rendered fluid by the heat of a furnace,

Conlabefactatus rigor auri ſolvitur æſtu.

If nature then is provided by its author with an element of ſuch power and activity, as enables it to *overcome* the ſtrongeſt coheſions; it cannot be deſtitute of an agent powerful enough to *cauſe* them: if it can do the greater, it muſt certainly be able to do the leſſer. And without much diſputing, do we not find it to be thus in fact? For the æther, acting below a certain degree, will conſolidate the particles of water into ice: if it acts above that degree, it keeps the water fluid: if to an higher degree, it renders it more fluid: if to an higher ſtill, a total ſeparation of the parts will enſue. But if theſe parts mount up into the head of an alembic, where the action of the fire is different, they are united again into a well connected body. Theſe effects being anſwerable in every inſtance to the activity and condition of a *material* agent, what neceſſity is there for calling in the aſſiſtance of an unmechanical *attraction?* the work *may* certainly be done without it[*]; and I am verily perſuaded, ſuch a principle would never have been ſeriouſly defended, if the agency of fire had been ſearched into as it deſerves. If I can ſee the effects vary, as oft as there is any change in the element of fire, I am compelled, by all the rules of reaſon and philoſophy, to underſtand this element as the immediate *cauſe* of theſe effects, and muſt receive it

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[*] *Entia non ſunt multiplicanda abſque neceſſitate.*

at

as ſuch, till it is demonſtrated to be inadequate; the contrary to which hath been demonſtrated already, and might be farther confirmed by ſome other experiments, which I might here introduce, if there were any occaſion for them.

The cohesion of bodies by the action of this fluid, may be illuſtrated and confirmed in a familiar way by ſome parallel effects, in the explication of which we are all agreed. Let a ſtop-cock be faſtened to the neck of a bladder, that it may be ſcrewed upon the work of an air-pump: exhauſt the air from it; and having turned the ſtop-cock, to prevent the air from re-entring, take it off the machine *. The bladder is now transformed into two flat ſkins, ſo cloſely applied together, that the ſtrongeſt man cannot raiſe one of them half an inch from the other: for, ſuppoſing the bladder to form the area of a circle ſix inches in diameter, each ſide is preſſed down upon its fellow, with a force equal to 396 pounds. On the contrary, if the bladder be blown up with air, and the ſtop-cock turned to prevent it from getting out; it will be more difficult to bring the ſides together, ſuppoſing them not to be rent in the attempt, than it was before to ſeparate them.

I muſt be allowed to put a caſe here. Suppoſe a perſon, preſented with this ſpectacle, to be unacquainted with the preſſure of the atmoſphere; as many people undoubtedly are, and many of the learned alſo were, but little more than a century ago. What will ſuch a man ſay, when he is pulling at the ſides of the bladder, and finds it impoſſible to lift up either of them? If he is illiterate, he may think per-

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* This will anſwer as well without the formality of an air-pump. Only let the ſides of a bladder be preſſed flat together, while the neck of it is tied faſt to keep out the air.

haps they are bewitched: if he has any knowlege of philoſophical terms, he may ſay, "nature abhors a vacuum:" if he has any faith in the modern doctrine of a vacuum, he will take this to be an undeniable proof of a very ſtrong *attraction.*

When the bladder is blown up (allowing him ſtill not to be aware of any fluid within it) he muſt ſay the ſides *repel* one another; or he may call them *elaſtic*; attributing that elaſticity to the ſolid matter of the membrane itſelf, which is the property of the inviſible medium incloſed within it.

Attraction and repulſion, as here applied, are the creatures of this man's imagination, to ſay nothing of his ignorance. If he is fond of his fancied diſcovery, he will give himſelf no trouble about the real cauſe of theſe appearances, for he thinks himſelf to be already in poſſeſſion of it; and will not perhaps be very well pleaſed with thoſe, who endeavour to go farther, "for ever aſſerting his right to ſtop, "where he finds he can get no farther upon ſure ground [*]." Many philoſophers were grievouſly diſappointed, when the preſſure of the air was eſtabliſhed by experiment; the learned Dr. *Henry More* in particular, who oppoſed Mr. *Boyle* and profeſſor *Sturmius* with great vehemence upon this article. He had long indulged himſelf in the belief of an *hylarchical principle*, a *ſpiritus mundi hyloſtaticus*, which he deſcribes as a *living plaſtic nature*, but *brute* and *unintelligent.* And thus he ſolved, without any more expence than that of pen, ink, and paper, all the appearances of the viſible creation.

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[*] See the *preface* (of the editors) to Mr. *Maclaurin*'s account of Sir *Iſaac Newton*'s diſcoveries, p. 16.

We are apt to wonder in theſe days, how men of learning could thus ſupinely acquieſce in a ſet of occult and barbarous ſounds, and be ignorant of the weight of the atmoſphere, to which an experimental enquiry muſt inevitably have directed them. Yet our own practice at this time is in ſome reſpects no better than theirs; we have aſcribed an oracular dignity to a term, which has either no meaning at all, or many contradictory ones; a word that explains no more than the *principium hylarchicum*, and not quite ſo much as the *abhorrence of a vacuum* — But let us return to experiment again.

Instead of the bladder, let us now take two concave braſs hemiſpheres, known by the name of the *Magdeburgh hemiſpheres*, and firſt invented by *Otto Guericke.* They afford an appearance of the ſame kind, but more convenient to our purpoſe at preſent. Apply theſe hemiſpheres to each other: if you ſqueeze them ever ſo hard together with your hands, they are eaſily ſeparated afterwards, and moſt probably will fall aſunder by their own weight. What is the reaſon of this? Every fluid, we know, will naturally be *in equilibrio* with itſelf: the air, being here applied both to the inner and outer ſurfaces, will preſs with equal and contrary forces; which only deſtroy one another. But if the air be exhauſted from within, there will then be an exceſs of preſſure without, by which the hemiſpheres will be firmly fixed together. After this, if the air be again admitted they will fall aſunder as before.

Thus then let us argue: that as the air, when it enters, puts an end to this adheſion, by reſtoring an equilibrium, it is plain there was not an equilibrium before: the action from within, muſt have been weaker than the action from without, if the effect ceaſes when the former of theſe is made equal to the latter. And I deſire the reader to obſerve, that the offices both of *uniting* the hemiſpheres, and *ſeparating* them, are exerciſed on this occaſion by *one and the ſame fluid.*

If this reaſoning is juſt, the tranſition from the ſurfaces of the braſs hemiſpheres, to the coheſion of the braſs itſelf, will not be very difficult. For let this braſs be thrown into a furnace; it ſoon grows red; and as the heat increaſes, it becomes in a manner tranſparent: the matter of the fire penetrates into the body of the metal; and when the medium within is nearly in the ſame condition with the medium without, the braſs runs, and there is an end of its coheſion. An effect which is thus made to ceaſe in a mechanical way, may be produced in the ſame way; and if the entrance of the fire (as we argued above) diſſolves and ſeparates the parts of the metal; the exterior preſſure of the ſame element, though in a different condition, was the true cauſe of their coheſion.

Deny the exiſtence and preſſure of the air, and you muſt have recourſe to attraction, or ſuction, or an incorporeal agency, to account for the adhering of the hemiſpheres. Allow but the exiſtence and preſſure of elementary fire, the reality of which is manifeſt to as many of the bodily ſenſes as the reality of the air, and you need not have recourſe to any of theſe things to account for the coheſion of the braſs.

Between theſe two effects there will be a nearer and more apparent reſemblance, if the hemiſpheres, inſtead of being evacuated by the machinery of a pump, are heated moderately at a fire. The more ſubtil fluid, ruſhing into the concavity, expands and takes the place of ſome of the groſſer air, or *rarefies* it, as we commonly ſpeak. In this ſtate let them be applied, with a luting of any kind to the joint, and dipt in cold water: they will adhere as effectually as if part of the air had been withdrawn by exſuction. In like manner, when the fire diſſolves a maſs of metal, an extremely fine and ſubtil fluid paſſes freely through the body of it: but as it cools, this medium within, having no freſh ſupply, evaporates in part; and the remainder, growing continually weaker, yields to the ſuperficial preſſure of the ſame element, in a colder and leſs rarefied ſtate; from whence the whole effect muſt follow in a natural way; and the agent which drives the parts together, being univerſally preſent, will keep them together, till it is again counteracted as before. If any experimentaliſt ſhall hereafter be able to exhibit one ſingle inſtance of a cohering body, where he can prove the internal and external preſſures to be *equal* in all reſpects, we may then grant him his attraction; we may confeſs, ſuch an effect is not brought to paſs in a *phyſical* way; and that we underſtand no more of the cauſe of *coheſion*, than he has expreſſed under that *word*; which is juſt nothing at all.

In the mechanical way of ſolving the cauſe of coheſion, of which I have thus ventured to offer a ſhort draught, I perceive there is one article that wants to be explained and confirmed a little farther. It will be granted me, I preſume, that the matter of fire, by penetrating through the ſurface of a ſolid or fluid body, acts *internally* with an expanſive force, to looſen and drive aſunder its conſtituent particles. But where ſhall I find a medium to act *externally*, and overcome this motion of the fire when the body grows cool and begins to concrete? If I ſhould ſay, the *heat* within is counteracted by the *cold* without, and that cold is the agent acting externally, it will be aſked again, how cold, a mere *pri-*

vation, can be taken for an agent? But that cold is a mere privation, I cannot believe, becauſe experiment ſhews it to be the effect of a cold ætherial fluid, as heat is the effect of fire, an hot fluid. I cannot ſtop here to purſue this ſo far as it deſerves: it will ſerve my purpoſe at preſent, to prove the reality of a *cold æther*, different from common air, and of ſufficient power in its operations to execute the office I have aſſigned it.

Spring-water, it is well known, contains in it a large portion of air; and moſt of the medicinal waters, ſuch as *Pyrmont*, *Briſtol*, *Tilbury* &c. contain much more than the water of common ſprings. But there is an eaſy method of extracting all the air, ſo that no part of it ſhall remain. This is done by boiling the water, and then placing it within the vacuum of an air-pump. When it has remained in this ſituation till it is cold, it is ſufficiently purged of its air, and ready for the experiment I am about to propoſe.

Pour ſome of this water into a ſmall glaſs phial with a long and ſlender neck; obſerving withal, that the ſurface of the water is to reach no higher than to the bottom of the neck. Set this phial on a ſmall transferring-plate, and cover it with a glaſs receiver, from which exhauſt the air as perfectly as poſſible. Then plunge the receiver, with its included phial of water, into a freezing-mixture, compoſed of ſnow or beaten ice mixt with common ſalt, or powdered *ſal ammoniac*, which is better. In a very little time, your phial of water will be frozen into ice, which runs much higher into the neck of the bottle, and occupies more ſpace than the water did in its fluid ſtate. This intumeſcence, as you will perceive upon inſpection, is owing to a great number of *bubbles*, diſperſed within the body of the ice, which certainly are not compoſed of air; for air does not ſwell and rarefie with cold, but is always condenſed into a leſſer ſpace. Beſides, there was no air either in the water or the phial, neither can air penetrate the glaſs of the receiver; and if a ſmall gauge be included together with the phial, and the ice be melted after the operation of freezing, by bringing the receiver near a fire, theſe bubbles will riſe up and burſt at the ſurface, as the ice grows liquid; but after all, the gauge will not be affected by them, as it would be, if they were of the ſame nature with common air. When the ice is all reduced to water, and wholly cleared of its bubbles, repeat the freezing; you will perceive the ſame intumeſcence as before, and the ſame collection of bubbles: and thus it will happen *toties quoties*; as I can venture to ſay, becauſe I have been at the trouble of making this experiment, ſo far at leaſt as to ſatisfie myſelf of the truth of what I aſſert.

THIS ſubtil æther, though but ſmall in quantity when compared to the bulk of the water, is introduced with a force, which art would find it very difficult to meaſure; a force capable of burſting ſtrong veſſels of ſilver and braſs, ſuch as might be filled with air many times condenſed, without receiving the leaſt damage. The experiments of this kind, made in the academy *del Cimento* *, do well deſerve the attention of thoſe, who require any farther ſatisfaction in this matter; and to theſe experiments I refer, as to ſo many proofs of an æther, cold, ſubtil, adequate to all the effects of coheſion, and different from common air. It is true, I am not confined to theſe; there are many other ways of proving the ſame thing; and the phœnomena of electricity have ſerved to open the eyes of ſome few experimenters; ſo that I have the ſatisfaction to find, I am not ſingular in aſſigning a *mechanical* cauſe of coheſion.

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* See their experiments on *artificial-freezing*. p. 69 &c. But leſt it ſhould be thought, that the effects, I here refer to, were owing in any degree to common air, I muſt beg leave to ſubjoin the following experiment. I made a ſtrong cylindrical box of metal, with a broad rim, to which a flat cover was applied ſo exactly, by grinding one upon the other in a turning-lath, that when the cover was laid upon the box, no light could be ſeen through the joint. Then I prepared ſome water, by boiling and placing it upon an air-pump. This water, when cold, was ſo throughly purged, that it would not yield the leaſt bubble of air, when the pump was well evacuated; and this I tried immediately before the uſing of it. I filled the box with ſome of it, till it ſtood convex above the rim: and having applied a wetted leather to the cover, ſcrewed it down firmly upon the box with four iron ſcrews; by means of which, it was made *air-tight*: and in this ſtate, I ſuppoſe, the box and cover would not have been ſeparated by a weight equal to half a ton, and perhaps not by a great deal more. Having plunged the whole into a freezing mixture, the water was frozen into a ſolid maſs in leſs than half an hour; and as its bulk increaſed, by means of the incloſed bubbles of *cold*, three of the ſcrews were

THE ingenious Mr. *Wilſon* F. R. S. in his *treatiſe on electricity*, p. 187, is of opinion, "that coheſion may ariſe from "the mutual action of the *light contained within bodies*, and "of the atmoſpherulæ ſurrounding them, the preſſure of "which alone may be ſufficient to make their particles co-"here with a great force &c." Dr. *Boerhaave* alſo hath dropt an hint, as it were by accident, which greatly favours what I have advanced. "If therefore (ſays he) *cold* were a mere "*privation* of fire, the power which *contracts* the particles of "a ſolid body, would be innate, or implanted in the nature "of body itſelf; while the power that *expands*, would de-"pend upon the fire, and conſequently be ſomething extrin-"ſic." See *Boerh. Chym.* by *Shaw.* Vol. I. p. 219. He ſeems here to me, to mention this as an abſurdity in nature. And ſurely it is incredible, that bodies ſhould be *relaxed* by the force of a *medium*, and *conſolidated* by an *attraction* in the matter: in other words, that the particles, of which they conſiſt, ſhould be moved outwards, from A to B, by a mecha-

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forced by the violence of the preſſure, and the cover was raiſed up on one ſide, about a quarter of an inch above the rim.

Common air, it is certain, could have no ſhare in this effect; the whole being occaſioned by a finer *æther*, ſo ſmall in quantity, that it did not occupy a cubic inch; and ſo great in force, that its preſſure muſt have been an *hundred times* greater than that of the atmoſphere, which is only *fourteen pounds* upon a ſurface of an *inch ſquare*.

mechanical force, and brought back again, from B to A, by an occult quality. Would this be agreeable to that uniformity, which is every where to be obſerved in the ways of God? it muſt follow therefore according to the ſuſpicion of this author, that cold is not a privation of fire, but occaſioned by ſomething as *real** and poſitive, as that *fire* which is the occaſion of *heat*. I ſay no more in this place, having conſidered this point particularly in the enſuing pages.

THERE are another ſort of reaſoners amongſt us, who ſeem to glory in their ignorance; and have precipitately defied *all the philoſophers upon earth, to account for* coheſion, *otherwiſe than by the power of the Deity immediately intereſted*. After the extravagant lengths theſe gentlemen have gone, for the ſake of gaining ſome credit to I know not what metaphyſical reveries, they muſt be endued with a degree of candour and ingenuity rarely to be met with, if they will attend to any thing of this kind. But I muſt beg leave to remind them, that if they will account for coheſion by immaterial impulſes and miracles, they ſhould account for the adhering of the two exhauſted hemiſpheres after the ſame manner, and deny that the air is employed as an inſtrument in this buſineſs. For I humbly think, it is conſiſtent neither with the wiſdom nor the power of God, that he ſhould ordain an inanimate ſubſtance to produce ſome effects, and produce other ſimilar effects by the immediate influence of his own divine eſſence, becauſe they are conceived to be beyond the reach of any inſtrument even of *his* contriving. Such a concluſion as this, no pious man, who is really concerned for the honour of God, can eaſily digeſt; and Mr. *Boyle*, I am perſuaded, would never have admitted it. Nature is extremely ſimple in its agency, though infinitely various in its productions: it is not made to act by corporeal impulſes for the production of ſome effects, and by attractions and ſpiritual influences for the production of others. Of this ſimplicity in nature, if we can truſt to their own declarations, philoſophers of all ages have been perſuaded; and it is no fault of mine, if ſome of them have unhappily departed from their own rules, and made nature to abound with almoſt as many cauſes as effects.

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* *Plato* is very clear upon this article, in the diſcourſe of his *Timæus Locrus* — το μεν ων θερμον, λεπτομερες τε και διαστατικον των σωματων δοκει ειμεν. Το δε ψυχρον, παχυμερεστερον πορων και συμπιλωτικον εστι. "What we call heat, conſiſts of very fine parts, which ſerve to ſeparate and "diſſolve bodies: but *cold* is made up *of groſſer parts*, which preſs upon and ſtop up their "pores." *Plat. Op. Serr.* Vol. 3. p. 100.

CHAP. IV

An experiment *to confirm and illuſtrate what has been advanced in the foregoing chapter: with ſome obſervations on* heat *and* cold.

I Should very far exceed the bounds I have preſcribed to myſelf, were I here to run through the natural hiſtory of coheſion, and diſtinguiſh all the variety of caſes I have collected, ſome of which may be intricate and difficult enough, whilſt others would ſerve to clear them up, and confirm the principles I have advanced. I cannot however forbear to ſelect one example, as it ſeems to yield us a palpable proof, that coheſion is cauſed in the manner I have ſuppoſed.

There is a toy made in our glaſs-houſes, which the learned have treated of under the name of *lachryma vitrea*; the workmen call them *glaſs-pears*, and they are commonly ſold in *London* for the diverſion of ſchool boys; though they are attended with a phœnomenon, which hath excited the admiration of moſt of the philoſophers in *Europe*. They are made of the ordinary green glaſs, by letting fall a large drop of it, when in fuſion, into a veſſel of cold water. If a piece of the neck be afterwards broken off from the drop thus prepared, the whole body of it burſts aſunder with an exploſion, and is ſplit into a thouſand ſmall fragments, which may be crumbled into duſt without any injury to the fingers. This effect, wonderful as it is, may eaſily be traced up to its cauſe.

It was obſerved above, that as a melted metal grows cool, the fire that had been lodged within it, evaporates by degrees; while a colder æther, preſſing on the ſuperficial parts, brings the whole to a due firmneſs and coherence. Here we have a noble illuſtration of it. The fire, having rarefied the particles of the glaſs, and put them into a ſtate of fuſion; the cold, applied ſuddenly by the water to the ſuperficial parts of the drop, forms a condenſed cruſt of glaſs over the whole, before the fire within has time to eſcape in a regular way. By this means, the inner particles are cloſed up in their rarefied ſtate; and when all is cold, there remains between theſe particles what cuſtom, and the poverty of language, obliges me to call a *fire-vacuum*, analogous to the vacuum of an air pump. When a piece is broken off from the ſmaller end, a part of the *rarefied core* is immediately expoſed, the interſtitial paſſages of which are ſo open, as to admit an æther that ought to have been ſtopt by the ſurface: this æther ruſhing in ſuddenly, as air into an exhauſted veſſel, fills the pores with ſuch violence, as to rend the whole ſubſtance into atoms. The channels formed by the diſpoſition of the pores, muſt likewiſe be of ſuch a figure, as will contribute not a little to the ſucceſs: for as the matter of the glaſs decreaſes in its rarity from the axis of the drop toward the circumference, all theſe channels will repreſent the figure of a *wedge*; the propriety of which in this caſe, and the conſequences that muſt attend it are clear enough.

It is not *air* that occaſions this effect, becauſe it will anſwer beſt *in vacuo*; and what is very much to my purpoſe, it is then attended with a flaſh of *light*; for the obſervation of which curious circumſtance, we are indebted to the *French academy*[*].

In ſome trials, the progreſs of the effect hath been ſuch, as plainly to point out the true and natural ſolution of it. *Franciſcus Redi*, who publiſhed 41 different experiments upon theſe bodies, without adding one word of enquiry after the phyſical cauſe, informs us, that when he had coated one of them with plaiſter of *Paris*, leaving out ſome part of its tail to be afterwards broken off, the coating was rent by the exploſion at the baſis of the drop; "as if the force of "the fracture took its riſe at the extremity of the tail, and "paſſing downward from thence to the baſis or bottom, "forced away the plaiſter of *Paris* in that place" [†].

It is farther remarkable, that if one of theſe bodies be laid upon hot coals, or boiled in oil, and doth not burſt in the operation, (which very frequently happens) it is reduced to the temper of common glaſs, that hath been regularly *annealed*; and if its neck be ſnapped off, the uſual event does not follow. The fire relaxes the indurated cruſt, and having gained a paſſage through it by ſlow degrees, fills up the pores of the glaſs without violence; after which, it grows cool with a more equal and regular diſpoſition of the parts.

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[*] *Hiſt. de l'Acad.* 1692. p. 307.

[†] Guttula rumpendo vim baſin verſus faceret, & in eâ parte laceraret gypſum, ac ſi vis rapturæ originem caperet a principio caudæ, iretque ſemper impellendo verſus baſin aut fundum guttulæ. *Redi Obſerv.* p. 61.

If theſe things ſhould not appear to others in the ſame light as to myſelf, I cannot help it. I leave it to be conſidered, whether we ſhould not come much nearer to an agreement, if inſtead of attempting to annihilate the agents God hath created, they would ſpend ſome labour upon the ſtudy of them, and examine the wonderful effects of the ætherial elements, without a reſolution to find attraction and a *vacuum*, where no ſuch things ever exiſted. The effects of heat and cold, as daily exhibited to our ſenſes in the cuſtomary changes of the weather, are ſufficient to juſtifie me in what I have deduced from them. When the weather grows warm, the power of coheſion grows weaker; when the weather becomes cold, this power is increaſed; and the hardeſt of metals, in common with all other bodies, are proportionably altered in all their dimenſions. Extreme heat will diſſolve them; extreme cold will harden, and render them ſo brittle, that large bars of iron may be eaſily ſnapt in ſunder, after they have been expoſed all night to the open air in a ſevere froſt. A power of ſo fluctuating a nature, and which is thus rendered greater and leſſer with every change of the elements, can be no property of the cohering matter.

If the changes of the atmoſphere are found to make the heights of the mercury in the barometer vary; who can doubt, that the *preſſure of the air* is the ſole and adequate cauſe of its ſuſpenſion? and accordingly, if the air be totally removed from the ſurface of the ciſtern, the mercury drops to a level with it. Therefore it hath never once been ſuggeſted to us, that mercury is endued with the property of flying up into a glaſs tube.

THUS alſo, if the degrees of denſity in a cohering body, vary with the degrees of heat and cold; where ſhould we ſeek, but in the element of fire, for the true and phyſical cauſe of coheſion? when we deſcend indeed to the preciſe mode of its operation, it is hardly to be expected our ideas can have a mathematical exactneſs. I take it for granted they are very groſs, and ſuch as we ſhould be aſhamed of, if the ſenſe of man extended to the firſt principles of matter, which God, in great wiſdom, hath purpoſely placed out of of his reach. But it is no inconſiderable ſtep in philoſophy, barely to determine the queſtion, whether God hath choſen to act by material inſtruments, or immaterial influences: it being of the utmoſt importance in every ſcience to begin rightly, and have our labours directed into a proper channel.

AS it will probably be much doubted, whether the operations of heat and cold are to be aſcribed to elementary fire, as to one and the ſame ſubſtance; that matter, I think, may eaſily be adjuſted by obſerving what happens to a common thermometer. When you bring it near a fire, and find it riſes from 55 degrees, the point of temperate, to 212, the degree of boiling water; to what ſubſtance do you impute this, and what is your name for it? doubtleſs you will tell me, it is elementary *fire*. Suppoſe the thermometer to be fallen 32 degrees below the point of freezing, and to be raiſed from thence up to temperate; during the greater half of which motion, a very ſevere *coldneſs* is predominant. Now if you imagine heat and cold to be things different in their nature, you muſt provide one element to raiſe the thermometer through the upper parts of its ſcale, and another to raiſe it through the lower; and after all, you will never be able to gueſs at any point of diſtinction, where the one ends and the other begins. For if your inſtrument, when expoſed out of doors, ſhould ſtand at 55 degrees in *January*, the air would be attended with a very ſenſible *warmth* to the body, and you would find yourſelf able to ſit very comfortably without a fire. If it ſhould ſtand at the ſame point in *July*, you would complain of ſhivering with *cold*, and perhaps order a fire to be lighted. Thus you will give the contrary appellations of *hot* and *cold* to one and the ſame temperature of the air; and if you realize theſe different ideas, which ariſe wholly from a deceived ſenſation, and ſearch after a ſpecies of *frigorific particles*, *acids of the air*, and ſuch like, you diſcover nothing real in nature, but become the dupe of your own language.

HEAT and *cold* are the names we have given to the ſenſations which are raiſed in us by the different (and ſometimes by the *ſame*) impreſſions of elementary fire. If an effect is produced when the thermometer ſtands at the heat of boiling water, I call it *fire* that produces it: if water is frozen into ice, and the thermometer ſtands at 30°; I am ſenſible of cold in my body, but the agent in this caſe is elementary fire: and there may be a greater philoſophical propriety than we are aware of in that expreſſion of *Virgil* — *Penetrabile frigus adurit* *. As we do not look upon *air* to be one kind of element when the barometer ſinks to 28 inches, and another when it riſes to 31; the element of *fire* ought to be conſidered in the ſame way, under all the different ſtations of the thermometer, that is, all the different degrees of heat and cold.

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* Georg. L. I. 93.

UPON theſe conſiderations, I have followed the moſt eminent of the chemiſts, and ſome modern writers on electricity, in uſing the word *fire* in its largeſt ſenſe, when I mean either *fire*, or *light*, or *æther*. We may indeed call it by any of theſe names, becauſe the ſame fluid muſt be underſtood by every one of them: though if we were to ſtand upon ſtrictneſs and propriety of expreſſion, it would be neceſſary, on ſome occaſions, to uſe the firſt of theſe; on others, only the ſecond or the third. When this fluid is cold and inviſible, or appearing only in pellucid bubbles like air, as in the *freezing-experiment*, let us call it *æther* — "cæcus ignis expers luminis [*]." When it becomes viſible and lucid, it is what all men have agreed to call *light*. When it gives heat and burns, it is *fire*. The employment moſt agreeable to me, is to ſearch after *things*, and try to render *them* intelligible: if I can but be ſo fortunate as to make ſome little progreſs in that reſpect, I leave the reader to correct my expreſſions, and ſettle the application of words at his own diſcretion. If he has had patience enough to follow me thus far, I hope he will hear me out, while I examine the nature of another ſort of power, oppoſite to attraction, and diſtinguiſhed by the writers of theſe times under the name of *repulſion*.

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[*] *Du Hamel.*

CHAP. V.

Of the phyſical cauſe of repulſion; *particularly as this principle is applied to the* elaſticity *of the* air.

IT is needleſs to repeat all the inſtances commonly urged, either to illuſtrate the operation or prove the reality of ſuch a principle as *repulſion*. The beſt-known, and moſt univerſal of theſe, is the *elaſticity* of the *air*; the property by which it reſiſts any compreſſing force, and which the great Sir *Iſaac Newton*, and others, have endeavoured to account for, by ſuppoſing a *repulſive force* to be implanted in its particles: for thus, it is preſumed, they may drive each other farther off, without the intervention of any other matter *.

If *repulſion* is propoſed to us, as a diſcovery of the *cauſe* of this property in the air, common ſenſe will remonſtrate againſt ſuch an impoſition. Experience will teach us, that the particles of the air are by ſome means or other repelled to a certain diſtance, and cannot be forced into immediate contact, by any power we are acquainted with. To inform us, this is owing to a *repulſion*, is but to tell us (by uſing the noun ſubſtantive inſtead of the verb) what we knew before, namely, that the particles *are repelled*. Repulſion is the *fact*; the *cauſe* of repulſion is ſtill to be enquired after.

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* "Which vaſt contraction and expanſion (of the air) ſeems *unintelligible*, by feigning "the particles of air to be ſpringy and ramous, or rolled up like hoops, or by *any other* "*means than by a repulſive power*." *Newt. Opt.* Q. 31.

Mr. *Boyle*, always ready to offer ſome mechanical ſolution of what occurred to him, ſuppoſes the aerial atoms to be a ſort of elaſtic ſpirals, like *watch-ſprings.* Thus they may reſiſt any incumbent preſſure, and naturally reſtore themſelves to their former ſtate, when that preſſure is removed. *Bernoulli*, who ſtudied the æther in a mathematical way, gives up this whole affair as an *inexplicable myſtery of nature* *, when his own principles might have helped him to underſtand it: and *Du Hamel*, a famous *Carteſian*, embraces the hypotheſis of Mr. *Boyle* as abſolutely *neceſſary* †.

But if ſome circumſtances are laid together, this neceſſity will ſoon diſappear; becauſe if it be admitted, it will carry us into very great abſurdities. The ſteam of boiling-water, as we find by its effects, is equally elaſtic with the air; and is therefore applied to give motion to a fire-engine for draining the water out of mines, in the performing of which, a very great power is requiſite. The force of this ſteam in *Papin*'s digeſter is incredible; and, without due caution, would burſt the ſtrongeſt veſſel. In the *Æolipile*, it appears as an extemporaneous air, and its *elaſticity* is as manifeſt as that of the air. Are the particles of *water* then of a ſpiral-like form? and is this ſuppoſition *neceſſary?* If it is not neceſſary to account for the elaſticity of water, it cannot be ſo to account for that of the air. Fire, which acts upon the former of theſe, and by expanding renders it elaſtic, may produce the ſame effect in the other ‡. It would be abſurd to feign a ſet of ſpringy particles in water; this fluid in its ordinary ſtate being reputed unelaſtic: and in fact, no author I have ever met with hath been ſo unreaſonable as to ſuppoſe ſuch a thing. The particles even of mercury itſelf, ponderous as it is, when ſublimed by the impulſe of fire, become elaſtic like air or water, and will burſt the veſſel in which they are confined. When a drop of mercury is thrown into a naked fire, it hiſſes and explodes like water. Is *mercury* alſo compoſed of ſpringy particles? or rather, do they not manifeſtly borrow from the impulſe of fire all the elaſticity they are endued with? For if the agency of the fire be ſuddenly checkt, the elaſticity of mercury, of water, and of air alſo, in its proper degree, departs together with it.

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* *De Gravit. Æther.* p. 81.

† *De Conſenſu Vet. & Nov. Phil.* p. 220.

‡ Aquarum enim quaſi vapor, quidam aer habendus eſt. Is autem exiſtit *motu ejus caloris*, qui aquis continetur. Cic. *de Nat. Deor.* L. 2. 10.

The true cauſe of this elaſticity hath been acknowleged by ſome ingenious men, whoſe labours were ſure to be attended with ſome ſucceſs, becauſe they argued with facts before their eyes, and endeavoured to examine them to the bottom. It is greatly to be wiſhed, that all philoſophers would do the like. Dr. *Shaw*, in his uſeful notes on *Boerhaave*'s chemiſtry, aſſures us without any heſitation, "that "the active force in *air*, which produces ſo many effects, "does really *all* ariſe from the *fire* contained in it [*]." And Dr. *Alex. Stuart*, in his lectures on muſcular motion, which contain ſome curious obſervations in anatomy and phyſics, has the following words — "Thus it appears that this ex"panſion and *repulſe* is not owing to the natural elaſticity "of the air, but to a foreign power, to wit that of *fire* act"ing upon it;" which the author claſſes among the ſpecies of *fluids, viſible and obvious to the touch* [†].

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[*] Vol. I. p. 220.

[†] *Philoſ. Tranſact. abridg.* by *Martyn*, vol. 9. p. 285.

If it ſhould be ſuſpected, that I am taking refuge under the authority of others, and would thus impoſe a belief of what may not very eaſily be demonſtrated; only let a bladder, half filled with air, and cloſely tied about the neck, be brought near a fire: it will immediately ſwell; and the elaſticity of the encloſed air will increaſe, as the action of the fire upon it increaſes. If a bladder were blown quite full of air in the heat of ſummer, and preſerved till the depth of winter, it will have loſt much of its elaſticity, and be ſhrunk into a ſmaller ſpace. Thus, if a greater degree of motion in the fire gives *more* elaſticity, and a leſſer degree *leſs* elaſticity, to the ſame quantity of air; the element of fire appears to have the direction of this property, and is the immediate phyſical cauſe of it at all ſeaſons. That fire is always intermixt with air in a certain proportion, is evident from the thermometer.

This whole affair ſeems to be in a manner ſo ſelf-evident, that it would be idle to inſiſt upon it any farther. However, there is a powerful objection or two, to which I have never yet ſeen any reply: and certainly they deſerve to be carefully examined, becauſe they have been thought to countenance the doctrine of *repulſions*, *ſpringy particles* &c.

It is obſervable, that a flaccid bladder, placed under a pneumatic receiver, will be diſtended when a part of the air is withdrawn from the outſide of it, after the ſame manner as if it were held before a fire, but in a much greater degree. If fire is the immediate cauſe of this property, how can the repulſion increaſe, when the heat does not increaſe?

Mr. *Boyle* hath entitled this — "a diſcovery of the admirable rarefaction of the air, *even without heat*[*]." But this

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[*] See *Bolton*'s abrigd. V. 2. p. 249.

is not a juſt and proper repreſentation of the caſe: it ſhould have been ſaid “without any *additional* heat,” and then there would have been no obſcurity; an additional heat being not requiſite upon this occaſion. We need only appeal to a thermometer placed within the receiver, to prove the degree of heat *there* to be the ſame as without in the circumambient air. This heat is ſufficient for the purpoſe, and will neceſſarily produce a rarefaction within the bladder, when the veſſel that encloſes it is exhauſted.

So long as the receiver is full of air, of the ſame temperature with that in the bladder, there are two equal forces counteracting one another; there is air within the bladder, rendered elaſtic by the ſtanding degree of heat at that time in the atmoſphere; and there is air equally elaſtic, preſſing externally and with equal force, on the outer ſurface of the bladder; ſo that while things remain in this ſtate, all will be at reſt. But the effect will be juſt the ſame, whether you *add* more heat to the *inſide*, or *take away* an equivalent degree of the reſiſtance from the *outſide*: a rarefaction muſt follow upon either of theſe changes; and as fire is always exerting its force, it is eaſy to predict what the event will be, and what in reality it is found to be, when the reſiſting air is withdrawn. For ſuppoſe two men, of equal ſtrength, were puſhing, one on each ſide, againſt the door of a room, which will open either way: it will be the ſame in effect, whether you add another man on the inſide, or take away your man from the outſide; the door will be opened *outwardly* in either caſe. And thus it happens to the flaccid bladder upon the air-pump: to ſubtract the reſiſtance from its outer ſurface, is the ſame as to add a greater force of expanding fire to its inner.

A ſecond objection, which hath a plauſible appearance at firſt ſight, is drawn from this obſervation, that the air in a flaccid bladder, carried up to the top of a mountain, will be expanded; when, if fire be the cauſe of its elaſticity, it ought to be contracted; the air being much *colder* there, than in the valley below. This is nothing more than the former experiment under a new ſhape, and with the addition of a freſh circumſtance. When we aſcend a mountain, the barometer ſinks: that will cauſe the bladder to ſwell. At the ſame time the cold increaſes: that will cauſe it to ſhrink. It is to be enquired then, what proportion theſe oppoſite effects bear to one another. The reſult will be either two equal quantities, or two different ones. If the quantities were equal, the bladder ought ſtill to preſerve its dimenſions: if they ſhould prove to be unequal, the leſſer muſt be ſubtracted from the greater, and the effect will be equal to the remainder.

In order to adjuſt this matter from experiment, I find myſelf under a neceſſity of informing the reader, that I once made an excurſion into the peak of *Derbyſhire*, with the hope of improving my health, and adding ſomething to my little ſtock of botanical knowlege. I took this opportunity to examine the height of ſome of the mountains in the peak with a portable barometer, which I had made for this purpoſe, after the pattern of that deſcribed by *Scheuchzer* in his *itinera alpina*, with ſome little improvement. To this inſtrument I added a mercurial thermometer, graduated according to the ſcale of *Fahrenheit*. Upon one of the higheſt of theſe mountains, the barometer ſtood very nearly an inch lower than at the ſurface of the river which runs at the foot of it. This was in the beginning of *June* 1760, and the air was then unſeaſonably cold, the thermometer ſtanding, at noon-day, below the point of *temperate*. I muſt confeſs, the objection now before us was not then in my thoughts; otherwiſe I ſhould have been more exact in my remarks: but to the beſt of my remembrance, the difference I obſerved in the thermometer, when I had aſcended the top of this hill, amounted only to 2 degrees.

SINCE that time, I had occaſion to prepare an inſtrument, which performs the offices both of a thermometer and barometer, and renders all the momentary changes of the atmoſphere evident to ſenſe; for when it is expoſed to the ſhaded air, it is never at reſt, but ſhews us ſuch a perpetual agitation of the elements, as might ſuggeſt many uſeful and pleaſant reflexions; but they are all wide of my purpoſe upon this occaſion. It is ſufficient to obſerve, that when the barometer ſinks one inch, the ſpirits in this inſtrument riſe 15 inches perpendicularly in the tube: when the thermometer ſinks 2 degrees, the ſpirits ſink $2\frac{1}{4}$ inches. The motion of theſe ſpirits being occaſioned only by the ſwelling and contracting of ſome incloſed air, we thus find, without much trouble, what difference there is between the two contrary effects abovementioned. The *expanſion* of air, included in a bladder, and conveyed from the bottom of that mountain to the top, ſhould have been nearly as 15, on account of the ſinking of the barometer, and the leſſening of the incumbent preſſure; while its *contraction*, on account of the increaſing cold, would have been only as $2\frac{1}{4}$; which being deducted from 15, leaves $12\frac{3}{4}$ to expreſs the *real* expanſion of the air, inſtead of 15, which we may call its *potential* expanſion. This difference is ſo ſmall, and takes ſo little from the effect, that it would never be thought of in ſo groſs an experiment as that of the bladder: and the higher the mountain is ſuppoſed to be, the leſs would any ſuch interruption be taken notice of. A barometer would fall about 4 inches below its mean ſtation, at the top of a mountain, 1320 yards, or ¾ of a mile above the level of the ſea; at which height, the cold is uſually ſo great, that the ſnow lies continually. Let us ſuppoſe, that a thermometer, conveyed in the ſummer-ſeaſon from the foot of ſuch a mountain to the top of it, would fall from 60 degrees to 32, the point of freezing. The expanſion of ſome air, incloſed in a bladder, ſhould be as 60: but its contraction by the cold will be as 31½; therefore its real expanſion would be as 28½; and a flaccid bladder, inſtead of ſhrinking into a leſſer compaſs with ſo great a degree of cold, will ſtill be expanded *more than twice as much* as in the foregoing experiment.

These conſiderations have made me eaſy in regard to the immediate cauſe of the air's elaſticity. I heartily wiſh they may have the like influence upon others, and get the better of all their ſcruples. If fire, that univerſal and active element, can occaſion ſuch a property in the air, by a mechanical and impulſive motion, the thing is intelligible. By this means, we become poſſeſſed of one important truth in natural philoſophy, and ſuch as may in time direct us to many others. Could it once be ſhewn, that air, totally emptied of its fire, has any of this elaſtic property in it*, it would then be time enough to call in the aſſiſtance of *repulſion*, which is but the ſame thing with giving up the point as unintelligible. But unleſs elaſtic air can be exhibited under ſuch circumſtances (which cannot be, unleſs the thermometer be firſt made to ſink 290 of *Fahrenheit*'s degrees below the *freezing point)* there is no more occaſion for this quality than for that of coheſion.

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* Non tantum aer in ignem tranſit, ſed *nunquam ſine igne eſt*. Detrahe illi calorem, rigeſcet, ſtabit, durabitur. *Senec.* Nat. Quæſt. Lib. 3.

To thoſe who examine this matter impartially, theſe powers will appear incredible in their very nature. The effects which are explained by attraction and repulſe, do ſo often vary, that we are obliged to ſuppoſe the ſame particles of matter endued with both: with one virtue of drawing and alluring bodies; and another of terrifying and driving them away at the ſame time. But how, in the nature of things, can two principles, deſtructive of each other, reſide in the ſame ſubject? repulſion is as oppoſite to attraction, in my way of conceiving it, as darkneſs to light, or cold to heat; and it is equally impoſſible, that the ſame particle ſhould both attract and repel; as that it ſhould be both black and white, hot and cold, at the ſame time. To reconcile this, ſome have invented ſeveral concentric ſpheres, or *involucra* of contrary powers, ſurrounding the ſame atom of matter; ſo that when other matter approaches the atom, thus inveſted, as it were, with the coats of an immaterial onion; it meets firſt with a repelling ſphere; being forced ſomewhat nearer, it falls in with an attracting ſphere; and coming yet nearer, it meets with a repelling ſphere, to keep it from immediate contact. What a complication of cauſes is here! and all to make one poor atom vibrate through leſs than the 1000th part of an inch! This can never be agreeable to that ſimplicity of nature, ſo much boaſted of by all philoſophers; and if our own ſenſes are to have any weight, the experience of every day might lead us to ſomething more true, uſeful, and intelligible.

CHAP. III.

The application of coheſion, *as an* unmechanical *principle, ſerves only to keep us in ignorance. This is proved from a plain example.*

TO bring the argumentative part of this book to a concluſion, I ſhall take the ſubject of *vegetation*, and compare it with the favourite principle, which hath been applied of late years for the explanation of it by our ſyſtematical writers; in order to ſhew, by one example out of many, that theſe powers, which have unhappily been ſubſtituted in the place of the true agents, do not only not explain any effects, but tempt us to conceive falſely of nature, and to affirm what is contrary to experience. My only reaſon for driving the argument thus far, is to encourage thoſe, who pretend to be guided by *experiment*, to endeavour at ſome farther progreſs, and not *for ever aſſert their right to ſtop*, when they might go farther on with pleaſure and ſafety.

WHEN a glaſs tube of a very ſmall bore, is dipped into water, or any other fluid except mercury, the fluid will be raiſed to a certain height within the tube above the ſurface of the liquor in the veſſel; and its elevation, in ſeveral tubes of different ſizes, will be *reciprocally* as the diameters of their bores.

THE ingenious Mr. *Rowning* will have it — "it is drawn "up *by a tendency* it has by the principle of *attraction*, till "the ſurface is loaded with as great a weight as that *tendency*

" *dency* can ſupport [*]." Not to take advantage here of the author's terms (which to be ſure are unintelligible) let us for a while agree with him; and ſuppoſe the inner ſurface of the tube to *attract* the water. "*Hence* (ſays he) a "RIGHT NOTION of the aſcent of ſap in *vegetables.* [†]".

I. Now if the ſap aſcends in a vegetable, on the ſame principle that water riſes in a capillary tube, of which he ſeems to have no doubt; let us take a capillary tube, in which, for example, water will be raiſed to the height of *two inches.* In the tubes of a plant, therefore, whoſe bores are of the ſame diameter, the ſap ſhould be raiſed to the ſame height, but no higher [‡]. On the contrary, I have obſerved an heavy and viſcous juice to iſſue plentifully at the height of *two feet*; and that out of veſſels, conſiderably larger than the orifice of a capillary tube, within which pure water would not riſe to the height of two inches. It is hardly worth while to relate the hiſtory of ſo eaſy an experiment: however, the plant I made this trial upon, was a very large ſpecimen of the *tithymalus helioſcopius*, or common *ſun-ſpurge*, the trunk of which is without a joint, and was cut tranſverſely near the top of it; after which, a ſection of its veſſels was compared in a microſcope with a ſection of the glaſs tube.

II. It is alſo to be regarded, that the ſame quantity of liquor will be *ſuſpended* in a capillary tube when its lower orifice is lifted out of the water, as was raiſed into it while immerſed under the ſurface. Did the ſap aſcend into a vegetable on the ſame principle, it ought to *reſt* there, and be *ſuſtained* by the attractive power of the veſſels, when the orifices of them are expoſed to the open air. The contrary to which appears from experiment: for if a branch of the *birch* be taken off, or a young tree be cut quite away, and and held in the ſame perpendicular poſture in which it grew; the veſſels will bleed copiouſly from the bottom, as when a limb is cut off from an animal; and the like will happen in many other plants. Again; water will never run out at the *upper orifice* of a capillary tube, be it ever ſo ſhort. But the ſtump of a vine, as Dr. *Hales* hath ſhewn us[*], will ſend up its ſap into a tube cemented upon it, to the height of 20 feet and upwards. Theſe things being conſidered, it follows to a demonſtration, that the juices are not attracted by a plant, but forcibly compelled into its veſſels.

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[*] Pref. p. 17. 18.

[†] *Ibid.*

[‡] Dr. *Grew* has the ſame remark --- "although we ſee, that ſmall *glaſs-pipes* immerſed "in water, will give it an aſcent for ſome inches; yet there is a certain *period*, according "to the *bore* of the *pipe*, beyond which it will not riſe." *Anat. of plants.* p. 126.

III. In a capillary tube, it makes no difference, whether there is air on the ſurface of the water into which it is immerſed, or whether the air be exhauſted; the experiment ſucceeding equally *in vacuo*. And the ſame ought to ſucceed in a vegetable; to which, on the contrary, air is found to be ſo neceſſary, that no plant can take up its nouriſhment, nor will a ſeed ever germinate ſo long as the air is abſent.

IV. There is no ſeaſon of the year, in which a glaſs pipe will raiſe water to a greater height than at another; the effect being juſt the ſame in the depth of winter as in the heat of ſummer. But the rays of the ſun, or the heat of an artificial fire (which is equivalent) is ſo abſolutely requiſite to the growth of herbs, that in their ſeaſon for taking in the ſap, in their ſtature, and in their qualities, they are wholly influenced by the ſun's heat all over the world.

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[*] See Veg. Stat. Exp. xxxix.

The plants which are loweſt in their ſtature ſpring up firſt; as the little *aconitum hyemale* or *winter wolfs-bane*, which is the earlieſt of all; *arum*, *chelidonium minus*, *violets*, and a tribe of the like ſort, which ſeldom attain to many inches at their utmoſt growth, and appear very early in the ſpring. Theſe are ſucceeded by others of a larger ſize, till at laſt the under-ſhrubs and trees put forth in their order; and when the ſun is at his greateſt exaltation in ſummer, the whole vegetable creation is in its greateſt glory and beauty. Then as the ſun declines, this vegetative motion languiſhes; and the order they obſerved in putting forth their leaves, flowers, and fruit, is now inverted in their decay. The talleſt trees are generally the firſt that drop their leaves, and the lower follow at a proper diſtance, till by degrees the ſmalleſt ſhrubs, except the ever-greens, are all ſtript of their covering, and ſo continue, till the ſun at his return puts new life and moiſture into their veins. But what is all this to the aſcent of water in a capillary tube? to apply that experiment to the appearances in vegetation, is to introduce a principle to give us a *right notion* of every thing, which actually agrees with nothing in the whole ſubject.

There had been a fairer appearance of ſome foundation to build upon, had the aſcent of the ſpirits in the tube of a *thermometer* [*] been aſſumed as a proper fact to begin with:

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[*] "If in the morning (ſaith Dr. *Hales)* while the ſap was in a riſing ſtate, there was "a cold wind, with a mixture of ſunſhine and cloud; when the ſun was clouded, the "ſap would immediately viſibly ſubſide, at the rate of an inch in a minute for ſeveral "inches, if the ſun continued ſo long clouded: but as ſoon as the ſun-beams broke out "again, the ſap would immediately return to its then riſing ſtate, *juſt as any liquor in a* "*thermometer riſes and falls with the alternacies of heat and cold:* whence 'tis probable, "that the plentiful riſe of the ſap in the vine in the bleeding ſeaſon is *effected in the ſame* "*manner.*" *Veg. Stat.* Exp. 39.

and yet this, by itſelf, will fall very far ſhort of the purpoſe, though it may bring us ſomewhat nearer to the truth. For let a tube of this kind be fixed againſt a wall with a northern aſpect; the fluid contained in it will conſtantly perform like ſtages with the ſap in vegetables. Should it ſtand uncommonly high for the ſeaſon, vegetation will be unnaturally forward; of which this laſt winter* hath afforded us ſuch an example, as never occurred within the memory of man: violets, and ſome other plants, were obſerved to be in flower before the expiration of *old December*. When the thermometer is very low for the ſeaſon, vegetation will be at a ſtand. But generally ſpeaking, as the ſpring advances, it will be higher every month till the greateſt heat of ſummer; after which, when the trees begin to drop their leaves, the thermometer will ſubſide gradually, till it gets to the freezing point; at and about which, the motion of the ſap in vegetables is at its loweſt ebb.

Thus far we ſhould have been right with reſpect to the *agency*; though as to the particular circumſtances of it, we ſhould fail without ſome farther directions. But if we leave out the *ſun*, and the *celeſtial elements*, as things ſupernumerary to the natural world; and ſet up to explain all the wonders of vegetation, with no better furniture than the imaginary attraction of a glaſs pipe; we ſhall generate inſuperable difficulties of a new kind, and remove none of the old ones that naturally belong to this branch of philoſophy. Thus it will always happen, when we connect together things foreign to one another; and account for an hundred experiments, by one that *hath not been accounted for*; which is unfortunately the caſe with the *capillary tube*. Thus *Gilbert*,

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* 1760.

Kepler, and others, accounted for all the great phœnomena of the world, from thoſe of the *loadſtone*; and for thoſe of the loadſtone, *a formæ tantùm actu immateriali, ſeu incorporeo proceſſu* *. This magnetical philoſophy was once in great requeſt, but is now wholly diſregarded and forgotten.

I might have taken occaſion, in this place, to examine the affair of magnetiſm, and to prove, that the effect of the loadſtone is, 1. not owing to any attractive virtue in the ſubſtance, but 2. to the impulſe of an æther: and 3. that this æther is no other than elementary fire. But enough hath already been ſaid, to eſtabliſh the concluſion I had in view. It was not my intention, in this treatiſe, to compoſe any thing that ſhould look like a ſyſtem of philoſophy; but barely to ſettle ſome important *preliminaries*, which may ſerve as an introduction to the ſtudy of nature, and tempt ingenious men to make ſome farther enquiry upon mechanical principles. I doubt not, but that thoſe who are converſant in phyſical reſearches, will be able to confirm what I have ſaid, with many particular articles from their own obſervation.

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[*] *Gilb. de Magnete.*

CHAP. VII.

The concluſion from all the foregoing arguments and experiments.

IT may be of uſe now, to collect into one view the evidence that hath been offered; and to conſider at the ſame time, what, and how much, we have a right to conclude from it.

IN the proſecution of this work upon the *mechaniſm of nature*, I have endeavoured to diſprove all that hath been advanced on the other ſide of the queſtion; and to eſtabliſh the affirmative, by an induction of ſo many poſitive proofs from nature and experiment, as may ſerve to put it out of all diſpute.

1. FIRST then, it is clear enough, that the operations of nature *may be* mechanical; notwithſtanding all the objections, arguments, and demonſtrations, which have been invented to ſupport a contrary opinion. Some of theſe objections are no better than naked and unſupported aſſertions; which prove nothing, but that the authors of them were perſuaded of what they aſſerted. Other objections are drawn from the *difficulty*, which the learned have found, in aſſigning a mechanical cauſe for ſome particular effects; and theſe difficulties have been improved into abſolute impoſſibilities: as if it were impoſſible for God to contrive, what it is not eaſy for man to comprehend. *Coheſion* hath been a great difficulty: *gravity* another difficulty: and if there were five hundred more, would it not be wrong to draw any poſitive

concluſion, from what, by our own confeſſion, we do not underſtand? The induſtry and experience of future times, taking all due advantage of ſome modern diſcoveries, may make ſome things clear and eaſy, which at preſent are accounted unfathomable. And man, after all his labour in this life, muſt expect to find many difficulties, and have the mortification to be ignorant of many things. But how prepoſterous would it be, to begin a ſyſtem with thoſe articles, concerning which we have no certain knowlege! It would be like the practice of an architect, who ſhould undertake to build a church, and begin with the weather-cock.

As to *arguments*, the moſt important of all others, and that which moſt nearly affects the notion of an univerſal mechaniſm, is the proof of a *vacuum:* not only as the poſition itſelf doth neceſſarily exclude all ſecondary cauſes; but as it pretends alſo to be founded on facts. The barometer ſinks when it is carried higher up into the atmoſphere: but the argument, commonly deduced from this experiment, proves ſo much, that it proves nothing. For at this rate, there ought to be a vacuum, where our ſenſes, with the help of ſome common experiments, aſſure us there can be no ſuch thing. Fire, which burns and flames beyond the height to which the twilight is extended, will neither burn nor flame in a vacuum. Sound alſo is tranſmitted from thence, if accounts atteſted in the beſt manner deſerve any credit, perhaps more audibly than it would be at an equal diſtance upon the earth's ſurface. Theſe obſervations will not conſiſt with a vacuum: they will only lead us to ſuſpect, that the element of air is but imperfectly underſtood.

If we go higher up into the heavens, there again we meet with the *phœnomena* of *comets*; of the *philoſophy* of which bodies, but little more appears to be known, than that they diſprove the notion of a celeſtial vacuum: for they burn, and flame, and ſend out vapours, juſt as they would do, if the *air* were preſent to them. Sir *Iſaac Newton* hath been beforehand with us in ſtating this argument; though in oppoſition to his own opinion, upon ſome other occaſions.

From the *reſiſtance* of different mediums, a *demonſtration* is ſuppoſed to have ariſen for the proof of a vacuum, as abſolutely neceſſary to an undecaying motion. A body, it hath been aſſerted, muſt *loſe* its motion, by *communicating* it to the medium through which it paſſes: and this ſuppoſition is well known to be the foundation of that famous ſuperſtructure, which hath done ſo much honour to the geometrical talent of Sir *Iſaac Newton.* It is upon this account only, that he will have the celeſtial ſpaces to be void of all *ſenſible matter*; and thence he takes occaſion to introduce *attraction* and *projection* as the only poſſible cauſes of the planetary motions. Whereas in fact, a body may preſerve an equal pace through any medium, and its reſiſtance ſhall be no argument to the contrary, if that medium is appointed to act as the immediate *cauſe* of the motion. Nor is this a bare ſpeculation, depending on ſuch principles as muſt be committed to the courteſy of the reader; for the thing is reducible to practice.

Air is a reſiſting medium; yet inſtead of *retarding* the motion of the *lamp-machine* by its *reſiſtance*, it preſerves that motion by its impulſe. And if the motion is diſcontinued at laſt, this is not owing to any defect or irregularity in the *cauſe*, but to the imperfection of the *materials.* If the materials, which are acted upon, would but continue in the ſame ſtate, the motion would be unretarded, ſo long as air and fire, which are the cauſes of it, ſubſiſt in the world.

In this experiment, the cauſes are not *artificial* and *violent*, as when a circular motion is given to a ſtone whirled about in a ſling, or to bullets carried about in a box by the revolutions of a *centrifugal-table* &c. but ſuch as are ſupplied by nature itſelf, in its regular method of acting; which both *begins*, and continues the motion. What is done by nature in one caſe, may certainly be done in others. The planets themſelves may be carried round in their orbits by the ſame means. The heavens may be filled throughout with an ætherial fluid; not infinitely rarefied, unreſiſting, and impotent; but denſe, and continuous in its parts: for if ſuch a fluid is contrived, by the great author of nature, to govern and regulate the planetary motions; never let us fear, that it will obſtruct and retard *the motion which it gives*. From all this, we have ſufficient reaſon to conclude, that the operations of nature *may be* mechanical.

2. Nor is it leſs evident that they really *are* ſo. In all thoſe experiments, where there can be no reaſonable doubt about the explanation, matter is found to act upon other matter, for the producing of the effect; and we are able to trace this in ſuch a variety of inſtances, that unleſs the world is governed by oppoſite and contradictory principles, the ſame rule muſt obtain throughout the whole. The body of man, which is the higheſt piece of machinery in nature, is made to *ſee*, and *hear*, and *ſpeak*, upon mechanical principles; and it dies without the conſtant impreſſion of a *material force* upon it from the element of *air*. By the preſſure of this air, the mercury is made to riſe in the tube of a barometer: hail, ſnow, and vapours, are formed in the atmoſpherical regions, by the different temperatures of it: the clouds are ſuſtained by it, and driven about to water the earth: plants grow and are nouriſhed by it:

without it, there could be neither ſound, voice, nor language: all fires would be extinct: all animals, whether fowls, beaſts, or fiſhes, would periſh; and the whole world would languiſh and decay.

For thoſe effects, where the cauſe is not ſo obvious, a more ſubtil *æther* is provided; the reality of which hath been proved, and many of its operations pointed out by experiment. It is capable of being transfuſed, as an element, from one parcel of matter to another. On ſome occaſions, it will add a remarkable increaſe to the weight of bodies. It will enter the pores, and fill the interſtitial vacuities of all other ſubſtances; and it acts with a force, and a velocity, adequate to all the effects we can deſire to aſcribe to it. It gives an *elaſtic* force to *air*, and occupies every ſpace from which the air is exhauſted. In electricity, it ſhews itſelf to be *light*, and will occaſionally burn and conſume bodies as *fire*. It is therefore both light and fire: light, as it illuminates, and renders objects viſible; fire, as it burns and conſumes what it acts upon. In the fire of lightning, it appears by plain inference, to conſiſt of the ſame matter with the rays of the ſun; a conſideration, which, in common with many others, renders it univerſal to the whole ſyſtem of the creation.

3. These are the inſtruments, which God hath manifeſtly ordained, as ſecondary and ſubſervient to his own power, in the œconomy of the material world: and they are ſo univerſally extended, and incorporated with other things, as to be ſerviceable in the motion of all its particular parts. Some or other, and in many caſes each of theſe, are preſent to all thoſe effects which have fallen under the obſervation of philoſophers; and there are no other cauſes to be found; unleſs we aſcribe unintelligible and innate powers to

inert matter, thereby making the effect to be the cauſe of itſelf; or can ſuppoſe, againſt the dictates of reaſon and common ſenſe, that God, who hath created theſe means, hath made it a rule to act without them. Of theſe, both art and nature receive the benefit in common. What ſtrange things are brought to paſs by every ordinary blackſmith, only by the application of fire and air from his forge and his bellows? If he turns theſe out of his ſhop, the ſtrength of his hands will do him but little ſervice; and the reſt muſt be left to attractions and repulſions: but iron and braſs do not underſtand the force of ſuch philoſophy. What would the chemiſt do, without his furnaces and his refrigeratories? Hence proceed all his ſeparations, ſublimations, condenſations, fixations, digeſtions, chryſtallizations, and ſuch like. With the help of theſe natural cauſes, very few things are too hard for him; but without them, his whole art would be at a ſtand. The chemiſt ſees this and confeſſes it: he cannot but obſerve the uſes of fire and air within the ſphere of his laboratory; and is thence naturally led to acknowlege their uſes in the greater operations of nature. Hence it comes to paſs, that there are very few chemical writings extant, which will not afford ſome light to a natural philoſopher; but above all others, the writings of Dr. *Boerhaave* ought to be valued upon this account.

WHAT fruit then can be expected from the labours of any diſquiſitor, where he neglects theſe elements, and would baniſh them, to make way for ſuch cauſes only as can operate in a vacuum? he muſt of courſe deface the chief beauty of nature; which is no where ſo conſpicuous, as in the dependence that is eſtabliſhed between effects and their cauſes; and muſt empty the world of its matter and mechaniſm, only to fill it with difficulties and myſteries. If he deſtroys the connection between the parts of matter, he muſt preſent us with ſuch a picture of nature, as can reſemble nothing but the bones of a ſkeleton, which cannot ſtir one ſtep upon natural principles: whereas the work of God is worthy of its author, and the frame of nature is a perfect and well-connected body, furniſhed with all its proper muſcles and ligaments. The bones are united, moved, and lifted by the muſcles: if an anatomiſt, in deſcribing the wonders of the human frame, ſhould leave out theſe, he muſt ſuppoſe the bones to move themſelves; after which, he might go on to argue *againſt* the muſcles, as things uſeleſs and unneceſſary, mere obſtacles to the free and eaſy motion of the bones within their ſockets; and then he would philoſophize juſt as they do, who forget that fluid matter of the heavens, by which all other things are moved and connected together, and place occult powers in the ſolid matter of the celeſtial orbs.

To avoid falling into any errors of this kind, I have taken care to feign no arbitrary and abſtracted idea of nature; but have examined it wholly as a matter of fact, and have hitherto argued from obſervation only; in order to make ſuch a ſketch of its out-lines, as ſhall be like the original. And a ſtrong likeneſs hath often been hit by a very indifferent painter; while ſome finiſhed pieces, which have ſhewn a maſterly hand, might as well have paſſed for the figures of ſome fictitious characters in a romance, as for the perſons who ſat for them. With regard to my own reputation as a writer, I am perfectly eaſy: for it was neither my deſign, nor my deſire, to exhibit a pattern of eloquence; but to add ſome little matter to the common ſtock of uſeful knowlege. It is in this light only, that I could wiſh to have my labours accepted. As to the author himſelf, the learned, I hope, will find no reaſon to look upon him as one who would dictate to thoſe, who are better able to inſtruct him; or to impoſe a belief of any thing, which is not ſupported by plain argument, and undeniable evidence. If they do him juſtice, they will regard him only as a fellow-enquirer after that truth, which they alſo are deſirous to find; and will attend to him, as to one, who takes great delight in the works of God, and but little in any work of his own.

END OF THE THIRD BOOK.

BOOK IV.

The judgment of antiquity on the ſyſtem of nature: together with the ſentiments of ſome modern authors of the beſt repute.

CHAP. I.

Some general obſervations *on the* learning *of the* ancients.

TO what hath already been deduced from obſervation and experiment, let us now try, if we can add the ſanction of ſome clear and indiſputable teſtimonies from antiquity. This enquiry will be uſeful and pleaſant in itſelf, and the reſult of it, I hope, will be ſatisfactory; as it may ſerve to repel any charge of *novelty*, which, if it were well-grounded, might be urged with ſome ſucceſs againſt the doctrine of the *mechaniſm* of the world, and the influence of *material cauſes.* For, as I have pretended, that theſe things are equally *plain* and *important*, there could be no better objection againſt them as ſuch, than that mankind ſhould have been left to this day in ignorance of them.

For my own part, I have always been perſuaded, that in our judgment of phyſics, a proper regard ought to be paid to the concurrent teſtimonies of ancient writers; who had, in many reſpects, the ſame opportunities that we have, and made it their practice to derive their knowlege of things from evidence and obſervation. How far they were able to carry their obſervations, it would be difficult to ſhew with any tolerable preciſion; farther, I think, than they are allowed to have done by the general ſtream of modern writers; ſome of whom are weak enough to believe, that wiſdom is a child newly born, though the world is now in its dotage.

Thus much, however, is certain and indiſputable, that there are innumerable appearances and operations in nature, which are ſubjected to the eyes and ſenſes of men, though unaſſiſted with ſome inventions of art, which are uſually reckoned peculiar to the latter ages: and as nature is conſiſtent with itſelf, from theſe ſuch a judgment might be formed concerning the whole, as ſhould be ſubject to no material errors, though it might fall ſhort of a mathematical exactneſs.

The ſkill of the ancients in mechanical arts is generally confeſſed to have been very great; and there are ſome ſuch monuments of it ſtill remaining, both great and ſmall, as their ſons at this day would find it hard to exceed, or even to imitate. And it is well known, that in three branches of ſcience, very nearly allied to natural philoſophy, their attainments are the foundation of modern learning. Their *geometry* and *mathematics* ought to be remembered firſt upon this occaſion; the principles of which are derived from the writings of *Archimedes*, *Euclid*, *Apollonius*, and ſome other authors. And many of the moſt valuable parts of mathematical learning ſeem to have been more ancient than the names of the writers to whom they are aſcribed. The *Greeks* were always notorious for pretending to invent, what, it is evident, they were at the pains to glean up, among nations more ancient and wiſer than themſelves. The ſtory of *Pythagoras* ſacrificing an *Hecatomb*, when he had found out the 47th propoſition of the *firſt book* of *Euclid*, looks very ſuſpicious, and hangs ſo badly together, that the whole ſeems rather to have been a fiction. For how could that philoſopher ſacrifice an *hundred oxen*, who made it a point of conſcience never to ſacrifice any living creature? It is more probable, that his *geometry* was imported, together with his *aſtronomy*, from the *Egyptians* *, among whom he had travelled in ſearch of wiſdom and learning.

BUT it is a matter of no concern to the preſent argument, who were the inventors; thus much being certain, that the ancients were actually in poſſeſſion of all the moſt conſiderable and uſeful parts of the mathematical ſciences. It hath been ſuſpected, from ſome idle expreſſions among the poets, that the ancients judged the earth to be a *flat ſurface*, and that the ſun every evening went hiſſing into the weſtern ocean. Whereas it is known to thoſe who enquire farther, that their mathematicians always held the earth to be a *ſphere* as we do now; and ſome of them, from the earlieſt times of which we have any account, endeavoured to find out the meaſure of a degree upon its ſurface *, by the meridian-altitudes of ſtars near the zenith; a problem, in the ſolving of which, the *French* aſtronomers laboured ſo much ſome years ago.

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* Πύθαγοραν τε τα κατα τον ιερον λογον, και τα κατα γεωμετριαν θεωρηματα, και τα περι τους αριθμους, ετι δε την εις παν ζωον της ψυχης μεταβολην, μαθειν παρ' Αιγυπτιων —— Pythagoras *learnt from the* Egyptians *his knowlege of hieroglyphics or ſymbols*, *his* geometrical theorems, *his myſteries and powers of numbers, and alſo his doctrine of the tranſmigration of ſouls* ---- This is part of a famous paſſage in the firſt book of *Diodorus Siculus*, wherein that hiſtorian confeſſes, that the *Greeks* borrowed both their philoſophy and myſteries from the *Egyptians*. It is quoted by *Euſebius*, Præp. Evang. l. 10. and is printed at the end of the works of *Clemens Alexandrinus*.

THEN again, as to their knowlege of *phyſick*; how venerable are the names of *Hippocrates*, *Aretæus*, *Celſus* and *Galen*? and, what is worthy of obſervation, the author, who is the moſt ancient of theſe, is deſervedly the beſt reputed. Where the moderns take advantage of theſe writings, and form their judgment after the model of antiquity, it is always found to anſwer: and a phyſician of good abilities, who takes this courſe, is ſure to do honour to that profeſſion, which of all others is one of the moſt honourable.

THE modern anatomy is chiefly diſtinguiſhed from the ancient, by a knowlege of the circulation of the blood: and yet there are paſſages in ſome ancient writers, which ſeem ſo nearly to deſcribe it, though indeed with no great accuracy of expreſſion, that I confeſs I am not anatomiſt enough to ſee fully where the difference lies. They appear to have known, that the blood is thrown into the heart by the *vena cava*, and is diſtributed again, from the ſame fountain, to all the different parts of the body †. Whether they did actually infer, that it returned again to the heart through ſome capillary inoſculations of the veins and arteries[*], may indeed be queſtioned; and I would leave this to be determined by the phyſicians, whoſe reading is more extenſive, and whoſe proper province it is to judge of ſuch things.

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* This hath very lately been taken notice of, in Mr. *Stone*'s ſupplement to his new edition of *Bion*'s book on the *conſtruction and uſes of mathematical inſtruments*, p. 318; a treatiſe that ought to be in the hands of all lovers of mechanical and mathematical arts.

† Lapſus cibus --- in eam venam, quæ cava appellatur, confunditur, *perque eam ad cor* confectus jam coctuſque perlabitur: *a corde autem in totum corpus diſtribuitur.* Cic. *de Nat. Deor.* lib. 2. cap. 55.

In corde --- quatuor orificia, bina in utroque ventriculo: alterum quidem inducit, alterum vero educit --- per alterum *ſanguis trahitur*, per alterum *emittitur*. *Galen.* de uſu. part. L. 6.

It is obſervable that *Plato* in his *Timæus*, as quoted by *Longinus*, ſtyles the heart, πηγὴν τοῦ ΠΕΡΙΦΕΡΟΜΕΝΟΥ σφοδρῶς αἵματος. Long. p. 170. edit. Pearce.

BUT when I ſpeak of the wiſdom of the ancients, it is chiefly with a view to their knowlege of *Aſtronomy:* for although it may be doubted, to what original we ought to refer the whole merit of the invention, it is clear enough, that the true *ſolar ſyſtem*, revived by *Copernicus*, and confirmed afterwards by the teleſcopes of *Galilæo*, was well known to the aſtronomers of antiquity, who obtained it from *Egypt* and *Phœnicia*.

I cannot help obſerving upon this occaſion, what a miſchievous thing *authority* is, when it hath once gained a footing among thoſe who ſearch after the knowlege of nature. The name of *Ariſtotle*, and the example of king *Ptolemy*, gave a currency to a moſt unnatural and abſurd ſyſtem, and kept the world for many hundred years in a ſtate of darkneſs, from which it was recovered at laſt, not without great difficulty and violent oppoſition. There was a pleaſant inſtance of a philoſopher at *Florence*, whoſe prejudices had taken ſo deep root, that he could never be perſuaded to look through one of *Galilæo*'s teleſcopes, leſt he ſhould ſee ſomething in the heavens, that might diſturb him in his belief of *Ariſtotle*'s philoſophy.

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[*] That the blood hath ſuch a circulation as this, eſpecially in the *lungs*, ſeems to be affirmed by *Galen* in the following words, which I would deſire the learned reader to conſider: they are quoted by *Harvey*. Exercit. anat. I. cap. 7. *In toto eſt mutua anaſtomoſis* (inoſculatio) *atque oſculorum apertio arteriis ſimul cum venis; tranſumuntque ex ſeſe pariter ſanguinem & ſpiritum, per* inviſibiles *quaſdam atque anguſtas plane vias.* &c. That *Galen* knew the *arteries* to be filled with *blood* as well as the veins, is clear from his own experiments. "*Hippocrates* (ſays Dr. *Boerhaave*) has had the honour given him of knowing "the circulation, firſt by *Riclan*, and then by *Drelincourt* and others; but it is certain, "that if he underſtood the blood's motion, he has expreſſed himſelf ſo unintelligibly "about it, that his acuteſt interpreter, *Galen*, did not thence ſo much as ſuſpect that the "blood had a circulating courſe." &c. See Dr. *Boerh. Academical Lectures* --- Vol. 2. p. 38.

This ſame *Ariſtotle* informs us, that an aſtronomical ſyſtem, contrary to his own, was maintained by thoſe of the *Italic* ſect, who were called *Pythagoreans:* for theſe, ſays he, aſſert that fire is in the midſt of the world, and that the earth, moving as one of the ſtars, performs a circuit round this centre, by means of which the changes of day and night are brought to paſs. And the ſame author adds that many others beſide the *Pythagoreans*, judged it improper to place the earth in the centre of the world. *

ARCHIMEDES delivers it as the opinion and doctrine of *Ariſtarchus Samius*, that "all the fixt ſtars and the ſun are "without motion: that the earth is carried round the ſun "in the circumference of a circle, of which the ſun itſelf is "the centre: and that the ſphere of the fixt ſtars is ſo im"menſe, that the circle of the earth's annual orb bears no "greater proportion to it, than the centre of any ſphere "bears to its whole ſurface †."

LAERTIUS and *Stobæus* aſcribe the ſame doctrine to *Philolaus*. By the latter of theſe we are informed, that he "placed fire in the middle of the world, at the centre, and "called it the *focus* or *hearth* of the univerſe. ‡" From this philoſopher *Plato* is reported to have borrowed much of

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p. 38 of the *Engliſh* tranſlation ---- Thus far we muſt agree with this learned author, that if the ancients had a knowlege of the circulation, their expreſſions upon the ſubject are at leaſt defective, if not unintelligible. And it hath happened in many inſtances, that the truth hath never been ſufficiently cleared up and eſtabliſhed, until it hath been expreſsly diſputed. Certain it is, that the *Galeniſts* did abſolutely deny a circulation: in oppoſition to whoſe ſyſtem, the truth was either reſtored or diſcovered by the ſolid reaſonings and experiments of *Harvey*.

* Εναντιως οι περι την Ιταλιαν καλουμενοι δε Πυθαγορειοι λεγουσιν. Επι μεν γαρ του μεσου Πυρ ειναι φασιν, την δε γην εν των αστρων ουσαν κυκλω φερομενην περι το μεσον νυκτα τε και ημεραν ποιειν —— Πολλοις δ' αν και ετεροις συνδοξειε μη δειν τη γη την του μεσου χωραν αποδιδοναι. *Ariſt.* de Cœlo. L. 2. c. 13.

† *Archim.* Arenar. Lib. 1.

‡ Φιλολαος πυρ εν μεσω περι το κεντρον, οπερ Εστιαν του παντος καλει. *Stob.* περι ταξ. του κοσμου.

In his chapter περι ουσιας αστρων &c. he obſerves of the mathematicians, that ſome followed *Plato*; while *others aſſerted the ſun to be in the middle of the world* ---- φασιν μεσον παντων τον ηλιον.

of his knowlege; and according to *Plutarch*, he repented toward the latter end of his life, that he had not followed him in this article alſo.

Lastly, *Seneca* mentions it as a queſtion worthy of contemplation, “whether the univerſe revolves, the earth being “at reſt; or whether the earth moves, while the univerſe is “fixed. For *it hath been maintained by ſome*, that we, the “inhabitants of the earth, are carried about by an imper“ceptible motion; and that the riſing and ſetting of the “ſtars is not occaſioned by a motion of the heavens, but “that we ourſelves riſe and ſet here upon the earth*.”

The ancients therefore were acquainted with the diſpoſition of the world according to the true ſolar ſyſtem: and there is little doubt, but that the *Ptolemaic hypotheſis* was novel in compariſon of it, a ſcheme rather adapted to the prejudices of ſenſe, and the corrupt philoſophy of *Ariſtotle*, than eſtabliſhed in the world for any intrinſic merit of its own, or any rational conformity with nature itſelf. How plain and natural does the *Copernican* ſyſtem appear, now the induſtry of man hath been ſufficiently employed upon it: and how eaſily might it have been retrieved much earlier, if aſtronomers had not given up their underſtandings to what they never were able to make any ſenſe of. Men are always jealous enough of their bodily liberties, and are too often ready to claim a right of judging and contradicting, where they ought to be obedient; while they tamely give up the liberty of the underſtanding to thoſe who have no right to demand it, as *Ariſtotle* certainly had not. And yet his very name did once convey an idea of all that is great and wiſe, to thoſe who followed like a ſwarm of bees; and would ſhew an invincible affection, even for a dry unfruitful ſtump of a tree, if their leader happened to light upon it. It was owing to that idle un-enquiring ſpirit, which poſſeſſes moſt men, that the nations conquered by his pupil *Alexander*, were leſs numerous, and leſs ſubmiſſive, than the ſubjects of *Ariſtotle*; in the days of whoſe dominion, common ſenſe was in a manner buried and overwhelmed by a verboſe wiſdom, which employed itſelf only in diſtinguiſhing, ſubdividing, and diſputing, about its preſent ſtock of matter; not in the making of ſuch experiments, as might have corrected what was amiſs, and ſupplied what was wanting; becauſe the attempt would have derogated from the praiſes of *Ariſtotle*.

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* Utrum mundus terrâ ſtante circumeat, an mundo ſtante *terra vertatur*. Fuerunt enim qui dicerent, nos eſſe, quos rerum natura neſcientes ferat, nec cœli motu fieri ortus & occaſus, ſed ipſos oriri & occidere &c. *Nat. Queſt.* Lib. 7. c. 2.

The memory of *Nicolaus Copernicus* will always deſerve to be regarded, in that he was the firſt, who dared openly to ſet a better ſcheme on foot, in oppoſition to the furious prejudices of the age he lived in: and it is the greateſt praiſe of *Des-Cartes*, that his labours, for a time, gave a finiſhing ſtroke to the tyranny of ſcholaſtic learning. The divine providence itſelf ſeems to have favoured and ſeconded the attempt of *Copernicus*, in raiſing up *Galilæo*, to demonſtrate by his teleſcopes ſome articles not very eaſy of digeſtion, which *Copernicus* could only aſſert upon principle, without being able to confirm what he ſaid by ſuch ſenſible proofs, as the cauſe ſeemed to require. And *Galilæo* himſelf had piety enough to aſcribe this ſudden and wonderful turn of things to that ſupreme power [*], by whoſe direction all uſeful diſcoveries and improvements of ſcience are made to ariſe, at thoſe times and ſeaſons, when his wiſdom ſees them to be moſt expedient: though perhaps, in ſtrictneſs of truth, it may be more proper to term theſe *reſtorations of ſcience*, than original diſcoveries. And the farther I enquire, the more I am tempted to believe, that even in this ſenſe — *Nihil eſt ſub ſole novi.*

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[*] --- Ope perſpicilli a me excogitati, *divinâ prius illuminante gratiâ.* Galil. *Syder. Nunc.* p. 10.

THESE things are worth conſidering, before we enter upon the ſucceeding chapters: for there muſt needs be a fair proſpect of finding ſome very diſcernible footſteps of a true philoſophy among thoſe writers, from whom the true aſtronomy, after many ages, was ſo happily recovered. And in fact, we ſhall find them declaring ſo expreſsly and almoſt unanimouſly for the principles I have endeavoured to deduce and juſtify from obſervation, that if I had been allowed to invent ſuch expreſſions as ſhould agree beſt with my own ſentiments, they would have been juſt ſuch as I am able to produce. Some examples of this I have already given in the foregoing part of this work, by throwing a few paſſages occaſionally into the margin. I ought indeed to make ſome apology for ſetting out to view ſo many *Greek* and *Latin* quotations, in a treatiſe written in *Engliſh*. But how is it poſſible for me to avoid it? for we cannot have the ſentiments of the ancients without their languages; of which, however, I ſhall diſturb the text of my book with as little as poſſible.

CHAP. II.

Teſtimonies from the principal authors of profane antiquity among the Greeks.

PLATO, who was the head and founder of the *academics*, and without exception the greateſt and moſt amiable philoſopher among the *Greeks*, whoſe ſentiments alſo, in regard to natural philoſophy, are ſuppoſed to have been the ſame with thoſe of *Pythagoras* [*], denies a *vacuum* upon all occaſions, and aſſerts in general, that "fire and heat "beget and GOVERN all other things [†]." Where he deſcends to particulars, as in the dialogue that bears the name of *Timæus*, he accounts for the animal functions from an *intertexture of air and fire* [‡], acting throughout the whole frame of the body. To *fire* he aſcribes the office of *expanding within*, and acting through the body outwards; while the element of *air compreſſes from without*, and counteracts the force of the internal fire. *By the miniſtry of theſe cauſes* [**], and the impoſſibility of a *vacuum*, a *perpetual circulation*, as it were [††], is kept up, through the motion of the lungs in inſpiration and reſpiration. The effects obſervable in *gravitating* and *projected* bodies, as alſo in *amber* and the *loadſtone*, he imputes to the action of the ſame elements, and ſuppoſes them to be brought to paſs after a manner analagous to that above-mentioned: for in all theſe caſes, he obſerves, *there is really no ſuch thing as an attraction* *; but the *cauſes* already aſſigned will be found, *by thoſe who enquire diligently*, to effect all theſe wonders of nature by their *reciprocal impulſes*.

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[*] *Plato* is reported to have borrowed the doctrines in his *Timæus*, from the writings of *Philolaus* a ſcholar of *Pythagoras*. Theſe writings (as *Hermippus* relates) he purchaſed at the extravagant price of 40 *Alexandrian Minæ* of ſilver.

[†] Το γαρ θερμον τε και Πυρ ο δη και τ᾽ αλλα γεννα και επιτροπευει. *Theætet.*

[‡] Πλεγμα εξ αερος και Πυρος.

[**] Αις χρωμενον ΑΙΤΙΑΙΣ.

[††] Τουτο παν οιον τροχου περιαγομενου γινεται.

In another part of the ſame dialogue, ſpeaking of the manner in which viſion is performed, by the mediation of elementary fire and light, he ſays "Theſe are the *ſecondary* "*and co-operating cauſes* which *God* makes uſe of as *his* "*miniſters*, for the finiſhing and perfecting of his Work. "Moſt men look upon theſe, not as the *ſecondary*, but as "the *primary cauſes of all things*, inaſmuch as they occaſion "*heat* and *cold*, can effect the *coheſion* and *diſſolution* of bo-"dies, and perform all other things of this kind †." This paſſage while it ſuits my purpoſe, and ſhews how deep *Plato* was in the mechaniſm of nature, is ſuperior and contrary to the opinion of this author himſelf on ſome other occaſions ‡, and ſupplies us with a valuable teſtimony againſt the idolatry of the heathen world in general, who exalted the creature into the place of the creator. I know not how to account for this ſentiment from the mouth of *Plato*, unleſs it be taken for one of thoſe many articles, which this great philoſopher, to uſe the words of *Serranus* — *aliundè ex meliore doctrinâ acceperat*.

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* Παντων τȣτων ΟΛΚΗ μεν ȣκ εϛιν ȣδενι ποτε.

N.B. This paſſage may be conſulted at large, as well in the *eclogæ phyſicæ* of *Stobæus*, as in the works of *Plato* himſelf.

† Ταυτ᾽ ουν παντ᾽ εϛι των Ξυναιτιων, οις θεος υπηρετουσι χρηται, την τȣ αριϛȣ κατα το δυνατον ιδεαν αποτελων. Δοξαζεται δ᾽ υπο των πλειϛων ȣ ξυναιτια αλλ᾽ αιτια ειναι των παντων, ψυχοντα και θερμαινοντα, πηγνυντα τε και διαχεοντα, και οσα τοιαυτα απεργαζομενα.

‡ For the truth of this reflexion, conſult *Cicero* de Nat. Deor. lib. 2. c. 12.

Cicero, ſpeaking of the ancient *Platoniſts*, relates in few words how they treated the ſubject of natural philoſophy. "They divided nature into two parts, one of which was "*active*, the other *paſſive*. They held it impoſſible for bodies to *cohere*, unleſs they were kept together by ſome "force; and that it was neceſſary this force ſhould be exerted by *ſome matter*. In diſtinguiſhing the ſeveral uſes of "the elements, they attributed to air and fire the power of "giving motion and cauſing effects; to earth and water a "paſſiveneſs, or diſpoſition to receive their impreſſions [*]." *Cicero* ſeems here to have borrowed his ſenſe from ſome paſſages in *Ocellus Lucanus*, a *Greek* author of great antiquity, who was a diſciple of *Pythagoras*. He reduces all the different parts of the univerſe to what he calls "*generation*; "and the *cauſe of generation*; the latter of which, as obſervation teaches, hath the power of moving and affecting; "while it is the office of the former to be paſſive and receive motion. Heat and cold, which (according to his own "interpretation) are the δυναμεις or *faculties* of fire and air, "are the cauſes and efficients; the dryneſs and moiſture of the "earth and water afford them materials to work upon [†]." And this agrees with what *Hermias* the chriſtian philoſopher gives us as the opinion of *Pherecydes* the *Syrian*, who drew his learning from the books of the *Phœnicians*, and is reported to have been the teacher of *Pythagoras*, that "*æther* "*is the agent, earth the patient* [‡]."

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[*] De naturâ autem ita dicebant, ut eam dividerent in *res duas*: ut altera eſſet *efficiens*, altera autem, quaſi *huic ſe præbens* --- neque enim materiam ipſam cohærere potuiſſe, ſi nullâ vi contineretur: neque vim ſine aliquâ materiâ. --- Illa initia elementa dicuntur, e quibus *aer* & *ignis* movendi vim habent & *efficiendi*, reliquæ partes *accipiendi* & quaſi *patiendi*, aquam dico & terram. *Acad. Quæſt.* lib. 1.

[†] Φανερον οτι τω μεν την αιτιαν της γενεσεως το ποιειν και κινειν εστι. Περι δε το δεχομενον την γενεσιν το πασχειν και το κινεισθαι. *Ocell. Lucan.* cap. 2. Το μεν θερμον και ψυχρον ως αιτια και ποιητικα· το δε ξηρον και υγρον ως υλη και παθητικα. *Ibid.*

[‡] Ο μεν αιθηρ το ποιουν, η δε γη το πασχον. *Bochart.* geogr. ſacr. p. 236.

ZENO, who was the leader of the *ſtoics*, taught that "nature "is ſupported by an elementary fire diffuſed through all the "parts of it [*]. That there is no vacuity; the world being "ſo compleatly united in itſelf, that there is a connexion "and harmony between things celeſtial and terreſtrial [†]."

THIS mechanical connexion between the diſtant parts of the univerſe, was ingeniouſly expreſſed in a figure of the great *Diana* of the *Epheſians*, ſtill preſerved upon ſome ancient coins [‡]. This idol the ſame with the *Egyptian Iſis* [**] was plainly intended to repreſent the whole ſyſtem of nature. Her body is cloſely wrapt up and concealed from the head to the feet, under a variety of hieroglyphical ornaments, to ſignify the *firſt matter* of the univerſe hidden beneath the external *forms* and figures of things. (See plate III. fig. 3. page 129.) In her open face, is the ſplendor of the day; her veil behind ſhews the darkneſs of the night; her multitude of breaſts, the fertility of the earth, which as a fruitful mother ſuckles and ſupports all her productions: her hands ſpread out expreſs the efficient power or agency of the ſuperior elements; and to ſhew that theſe act only by means of mechanical impulſes, and a connexion with even the moſt extreme or loweſt parts of nature, a *chain* is carried down from each hand of the image, and connected with its feet. The ſenſe and meaning of this chain may be well expreſſed in the following words of a critical author of great learning — *In mundo ratione nullâ eſſe poteſt vacuum — etenim niſi nexibus mutuis colligaretur univerſitas, nec mundum natura contineret nec regeret, nec partium invicem ulla foret ſocietas* [††].

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[*] *Cic. de Nat. Deor.* lib. 2.

[†] *Diog. Laert.* Zeno.

[‡] See *Menetrii* Symbol. Dian. Epheſ. p. 10.

[**] Την δε της Ισιδος (τελετην) τη της Δημητρος ομοιοτατην υπαρχειν. *Diod. Sic.* ubi ſupra.

[††] *Cæl. Rhodigin.* lib. 1. c. 7.

The *golden chain*, let down from heaven to earth by *Jupiter*, requires the ſame interpretation; for *Plato* hath obſerved, that by this chain *Homer* meant to ſpeak of the *ſun*, that is, of the power and influence of the ſun upon terreſtrial things *.

If the ſun really does act upon bodies at a diſtance from him, it muſt be by means of ſuch a chain of matter. It was upon this conſideration, that *Voſſius* rejected the opinion of thoſe "who ſuppoſed the *æther* to be nothing but a "great void, in which the ſtars performed their courſes: "than which (as the ſame author obſerves) nothing can be "more contrary to reaſon. For it is neceſſary the heavens "ſhould be of a corporeal ſubſtance, that they may act "upon inferior things; which cannot be without either im"mediate contact, or the intervention of ſome ſubſtance ex"tended from the one to the other. Hence the ſyſtem of "the world muſt be continuous in its parts, or at leaſt con"tiguous, that things above may communicate their light "and heat to things below †." So agreeable is this both to reaſon and obſervation, that ſome writers, who in all appearance ſat down with a reſolution to maintain a *vacuum*, have at times yielded to the remonſtrances of common ſenſe, and relapſed into this doctrine of *Voſſius*, though in direct oppoſition to their own principles. We had an inſtance of this in *book* 2. chap. 3. But let us proceed with our enquiry.

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* Την χρυσην σειραν ως ουδεν αλλο η τον ηλιον Ομηρος λεγει. *Theætet.* See alſo *Macrobius* in Somn. Scip. lib. 1. But *Pierius* has an obſervation more to the purpoſe than any I have met with ---- *Juno catenâ de cœlo ab Jove ſuſpenſa, & lapides pedibus alligatos habens, ab* Homero *fingitur; ita ut unum pedem contractiorem habeat altero. Quæ imago quatuor elementorum ſymbolum eſt. Juno enim ipſa aerem ſignificat:* catena ignem, *quo cætera* colligantur &c. *Pier.* hieroglyphica. lib. LIX.

† Multorum ea foret opinio, quod æthera dicimus, nihil aliud eſſe, quam magnum inane, per quod ſidera ſuum conficerent curſum. Quos interea nimium quantum ratio fugit. Nam neceſſe fuit cœlum corporeæ eſſe ſubſtantiæ --- ut ſidera agere poſſent in inferiora, quod fieri non poterat ſine contactu, ſive is per ſe foret, & ſine corporis alterius interventu, ſive per aliquod fieret intermedium. Ut neceſſe ſit, omnia vel continua eſſe vel contigua ſaltem, quo ſuperiora poſſint inferioribus impertire lumen ac calorem ſuum *Voſſ.* de Orig. & Progr. Idol. lib. 2. p. 255.

After the *Academics* and the *Stoics*, the *Peripatetics* were moſt conſiderable. *Ariſtotle* their founder, though miſtaken in ſome things, was wiſe enough to concur with the beſt philoſophers of antiquity in diſbelieving and rejecting a *vacuum*. He attributed to nature an univerſal *abhorrence of a vacuum*, and accounted for many effects upon this principle, the merit and meaning of which, it is not worth while to enlarge upon in this place. Againſt thoſe who inſiſted on a vacuum as neceſſary to motion, he rightly argued, that "a "plenum is capable of being ſo affected, as to conſiſt very "well with the motion of bodies in it: for its parts may "yield mutually to one another, and give an eaſy paſſage "to bodies, though the ſpace in which they move is full of "matter. Of this, (he tells us) we have an inſtance in the "*circumgyrations* of *continuous* bodies, and alſo of *fluids*. "Nor does it follow that there is a vacuum, becauſe ſome "maſſes of matter may be compreſſed into leſſer dimen"ſions; for if water ſhould be forced into a ſmaller ſpace, "the air it contains would be forced out of it*." *Ariſtotle* might have added, that if *air* is compreſſed, the fire is forced out of it; the ſame rule being obſerved in all caſes of this nature.

It is very probable, that *Deſ-Cartes* might take an hint from this paſſage, to obviate that imaginary neceſſity for a vacuum, with which he was occaſionally preſſed by ſome learned men of his own time. He ſuppoſes a number of ſolid ſpheres to be diſpoſed in the form of a circle, and all of them in contact. One of theſe ſpheres cannot be moved forward in the circle, without moving all the reſt; ſo that the place of the ſphere firſt moved ſhall be inſtantaneouſly ſupplied by that next behind it: and thus the motion may be continued, though there is abſolutely no void interval between any of the ſpheres *. We have an example of this, when we give a circular motion to water or mercury contained in a cylindrical veſſel: the parts, though in motion, will ſtill preſerve their connection, and will occupy no more ſpace than when they were at reſt. The motion we are now ſpeaking of being *vortical*, yielded an illuſtration moſt agreeable to the phyſical plan of *Deſ-Cartes*: but a motion in the ſeveral parts of a plenum, is by no means limited to the form of a *vortex*; for when a liquor is *fermenting*, an inteſtine motion is generated among its parts in all directions, which will continue for ſome days; and if the liquor is ſet to ferment in a tranſparent veſſel of glaſs, the ſight is very curious. How very ill the continuance of ſuch a motion agrees with the vulgar inference from the *theory of reſiſtances*, I leave the mathematicians to conſider.

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* Αλλοιουσθαι γαρ ενδεχεται το πληρες· αλλα δε ουδε την κατα τοπον κινησιν· αμα γαρ υπεξιεναι αλληλοις ενδεχεται, ουδενος οντος διαστηματος χωριστου παρα τα σωματα τα κινουμενα. Και τουτο δηλον και εν ταις των συνεχων δινους, ωσπερ και εν ταις των υγρων. Ενδεχεται δε και πυκνουσθαι μη εις το κενον, αλλα δια τα ενοντα εκπυρηνιζειν &c. *Ariſtot.* Phyſ. lib. 4. c. 7.

From *Ariſtotle*, let us go next to *Hippocrates*, a man almoſt deified for his knowlege by thoſe of his own times, though he was not the maſter of any particular ſect of philoſophers. He had enriched his mind from the experience of earlier times, and derived a conſiderable part of his own ſkill from a diligent ſtudy of nature. His opinion in general may be learnt from the following paſſage " The element of

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* *Du Hamel* de conſenſu Vet. & Nov. Phil. p. 128.

“ *air* has a dominion over the human body, and is the prin-
“ cipal ſource of all things that happen to it, whether good
“ or bad. Its power and influence deſerve well to be accu-
“ rately examined; for wind is no other than a current of
“ air, rolling along in impetuous waves, which are ſo vio-
“ lent as to tear up trees by the roots, raiſe the waters of the
“ ocean into a ſtorm, and overwhelm and ſink the largeſt
“ veſſels to the bottom of the deep. Such and ſo great is
“ the power it exerciſes, though at the ſame time it is not
“ an object of our ſight, but manifeſt only to our reaſon.
“ What are the effects, to which air is not neceſſary? or in
“ what place is it not preſent? All the ſpace between the
“ heaven and the earth is filled with it. It is the cauſe both
“ of the winter and the ſummer. In the winter, it is con-
“ denſed and cold; and in the ſummer it is mild and ſerene.
“ The ſun, moon and ſtars are directed by it in their courſes;
“ for air is the aliment of fire, and fire that is deprived of
“ it becomes extinct: ſo that the ſun itſelf has a perpetual
“ motion by means of a pure and perennial air. The ſea
“ itſelf is impregnated with this element, becauſe the inha-
“ bitants of the water cannot ſubſiſt without it: in a word,
“ it ſuſtains the moon in its orbit, ſerves as a *vehicle* * to the
“ earth, and no place is void of it †.”

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* Οχημα, which is the word here, being rarely uſed for any thing but a carriage *moving* by land or water, for all the kinds of which it is a general term (as ſee *Jul. Poll. Onomaſt.* lib. I. c. 9. lib. 10. c. 12) ſhould imply a *motion* in the earth: but I know not how to reconcile this with what goes before, concerning the δρομος ηλιȣ or *courſe of the ſun*, unleſs we ſuppoſe *Hippocrates* to have alluded, not to the motion of the ſuns body, but the emiſſion of his *light*, to which the word ηλιος hath ſometimes been applied. Thus in *Mimnermus* περι βιȣ it it ſaid — οσσν τ επι γην κιδναται ηελιος; *quamdiu ſuper terram* ſpargitur *ſol*; which muſt ſignifie the *light* of the ſun, as ſurely as *Homer* meant the *light* of the morning, where he ſays ---- Ηως μεν κροκοπεπλος εκιδνατο πασαν επ' αιαν. And *Salluſt*, the Greek philoſopher, obſerves yet more expreſsly --- Του ηλιȣ την σφαιραν, και την απο της σφαιρας ακτινα ΗΛΙΟΝ εν συνηθεια καλουμεν. *De Diis & mund.* cap. 4.

† Ουτος δε (αηρ) μεγιστος εστιν εν απασι των συμπτωματων δυναστης —— το — κενεον δε ουδεν εστιν τȣτου. *Hippoc.* de flatibus. p. I.

THIS author having aſcribed ſo much to the air, you may ſuſpect, perhaps, that he has left no room for any other phyſical agent. He ſpeaks, however, as explicitly in other places of an univerſal *fire*; and particularly in his book *de diæta*, wherein he affirms, that this element "diſ-"poſes all things in the body after a manner proper to itſelf, "and according to the ſimilitude of the univerſe; ſo that "ſmall things are like to great, and great to ſmall: that it "is moſt powerful, hath an univerſal dominion, and go-"verns all things according to the order of nature; while "itſelf is ſilent, inviſible, imperceptible in its operations, and "in perpetual agitation [*]."

THUS far we have followed *Hippocrates* as a naturaliſt. If we conſult him as a theologiſt, he will tell us, that this *fire* is divine and intelligent, endued with mind, reaſon, and wiſdom [†], and to be underſtood as the fountain of theſe to all other beings! he confeſſes himſelf to have believed, that what is called *heat*, is immortal and omniſcient, capable of hearing and ſeeing, and acquainted with all things both preſent and to come. This, he adds, is what the ancients underſtood by *æther* [‡]. He ſpeaks of the *air* in the ſame ſtrain, as endued with *mind* and *underſtanding*, giving *ſenſe* to the brain as well as motion to the limbs [||].

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[*] Παντα διεκοσμησατο κατα τροπον αυτο εωυτῳ τα εν σωματι το ΠΥΡ, απο μιμησιν του Ολου, μικρα προς μεγαλα, και μεγαλα προς μικρα. —— Ισχυροτατον πυρ, οπερ παντων επικρατειται, διεπον απαντα κατα φυσιν· αψοφον και οψει και ψαυσει —— ουδεκοτε ατρεμιζον. *Hippoc. de Diæta.* p. 11.

[†] Εν τουτῳ ψυχη νοος φρονησις. *Ibid.*

[‡] Νυν δε αποφαινομαι αυτος εμεωυτου γνωμας· δοκει δε μοι ο καλεομενον θερμον αθανατον ειναι, και νοειν παντα, και ορην και ακουειν· και ειδεναι παντα τα οντα και μελλοντα εσεσθαι —— ονομηναι μοι αυτο δοκεουσιν οι Παλαιοι αιθερα. *Hippoc.* de carnibus. p. 1.

[||] Αηρ —— εισιων ες τον εγκεφαλον —— την φρονησιν και την κινησιν τοισι μελεσι παρεχει. *De morbo ſacro.* p. 89. ες το σωμα σκιδναται ο αηρ, καταλιπων εν τω εγκεφαλω εωυτου την ακμην, και οτι αν ῃ φρονιμον τε και γνωμην εχον. *Ibid.* p. 93.

THIS doctrine opens to us the whole ſecret of the pagan idolatry. The philoſophers of the heathen world were well acquainted with the influence of theſe elements over all other things; and being ignorant of the true and living God, judged it to be impoſſible that air and fire could perform ſuch wonders, unleſs they were divine; and therefore worſhipped them univerſally, as immortal and intelligent. This is the error, which *Plato*, having by ſome means obtained a better light, ſo clearly condemns, in that memorable paſſage, where he ſpeaks of phyſical cauſes. But it was an error ſo deeply rooted, that this ſublime philoſopher himſelf was not altogether free from it.

PHURNUTUS the mythologiſt confeſſes plainly enough, that the *Jupiter* and *Juno* of the *Greeks* were *fire* and *air*[*]. The former he deſcribes as the *ſoul of the world*, and imagines the human ſoul to conſiſt of the ſame ſubſtance. Their εκατηβολος *Apollo*, in the utmoſt ſublimity of its meaning, did certainly expreſs nothing higher than the *light* of the ſun; as it is evident from all the epithets and attributes aſcribed to this deity by the ancient poets and mythologiſts. *Macrobius* with a great compaſs of learning, and as great an appearance of truth, reduces all the gods of the *Gentiles* to the various effects and operations of the *ſun*. If the reader ſhould have any deſire to be farther acquainted with theſe things, I would recommend to his peruſal the treatiſe of *Phurnutus* upon the *nature of the gods*, and a part in the firſt book of the *Saturnalia* of *Macrobius*, from the beginning of the *ſeventeenth* to the end of the *twenty third* chapter: from all of which, he cannot eaſily fail of imbibing ſome taſte for the heathen *mythology*; a branch of the ancient learning, very curious in itſelf, and not without its uſefulneſs, when it falls into proper hands.

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[*] See the 2d and 3d chapters of his book *de Natura Deorum* ---- *Ignis* enim, id eſt *Jupiter* &c. *Fulgent.* Mythol. lib. III. c. 7. ---- *Juno* poſita eſt in ſimilitudinem *aeris*. Antiqui enim ipſam *Jovis*, id eſt *Ignis*, uxorem & ſororem dixerunt. *Albricus* de Deor. imag. cap. XI.

Tum *Pater omnipotens* fœcundis imbribus ÆTHER
Conjugis in gremium lætæ deſcendit, & omnes
Magnus alit magno permiſtus corpore fœtus.

Virg. Georg. lib. II. 326.

As the *Greeks* borrowed both their learning and their religion from the *Egyptians*, it is highly probable, that the philoſophy and theology of that ancient people muſt have coincided, even from the earlieſt times, with theſe placits of the *Grecian* ſages. And this is confirmed by the moſt early account we have of the *Egyptians*, in the ſacred writings. For the *miracles* in *Egypt* ſeem to have been chiefly calculated to aſſert an over-ruling power of the true God, and diſtinguiſh it from the above-mentioned philoſophical objects of the heathen worſhip, which were no other nor better than the works of his hands, though ignorantly and profanely dignified with the exalted attributes of omniſcience and eternity. The *Lord* is ſaid to have executed judgments upon the *gods of Egypt* [*]; which I cannot but ſuppoſe to have happened, when their *light* was turned into darkneſs; the *wind* brought locuſts, and ſcattered the aſhes of the furnace over the whole land; the heavens ſent down a ſtorm and tempeſt upon them, and *fire* ran along upon the ground, devouring and laying waſte the fruits of the earth.

These elements they worſhipped, not, according to *Plato*'s excellent diſtinction, as *ſecondary inſtruments* in the hands of God, but as the primary cauſes of all things, and the ſupreme Governors of the world; denying and rejecting the ſupremacy of that God of the *Hebrews*, who created the world in the beginning, does now ſuſtain the powers of nature, and will at laſt overthrow what they vainly believed to be immutable and eternal. It does not fall in with my deſign to ſay any thing of the other miracles; though they may eaſily be accounted for from ſome circumſtances in the hiſtory; whence it will appear, to thoſe who conſider the caſe attentively, that this cruel and oppreſſive people were *puniſhed* by the very things wherein they had *offended*; as it was obſerved long ago by the author of the apocryphal book entitled *the wiſdom of Solomon* *.

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[*] *Numb.* 33. 4. See alſo *Exod.* 18. 11. which is very expreſs.

The philoſophy of the more modern *Egyptians* is hardly to be collected from any expreſs teſtimonies, involved, as it is, under the obſcurity of emblems and hieroglyphics; which thoſe who have undertaken to explain, as *Horapollo*, *Pierius*, *Kircher*, and others, appear to have underſtood but very imperfectly. The ſafeſt way, therefore, is to collect the general intention of it, from what the moſt early philoſophers of *Greece* borrowed from them: the ſubſtance of which we have ſeen already.

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* See *chap*. 11. v. 6. 7. 16.

CHAP. III.

Some obſervations on the remains of the Chaldaic *philoſophy.*

OF the *Chaldaic* philoſophy there is little remaining, but a few fragments and mutilated paſſages; in which however there are ſome valuable hints, from whence a tolerable idea of it may be collected.

IN the oracles of *Zoroaſter* *, mention is made of an harmony or *melody of the* æther, *of the* ſun, *of the* moon, *and of all things that are ſurrounded by* AIR †. Whence it is clear enough, that the ancient *Perſians* and *Chaldeans* had no opinion of a *vacuum*; having thus filled all ſpace with *air*, and what they called an *all-nouriſhing æther*, to which they joined an *intelligent* and *life-giving fire* ‡.

SOME moderns, who have refined upon the theology of the pagans, and interpreted their creed ſo favourably, as to make it differ but little from the *chriſtian* doctrine, have ſuppoſed they worſhipped *fire*, only as an emblem or image of the deity, as the *romaniſts* make uſe of pictures to enliven their devotion: but the contrary is ſtrongly to be ſuſpected, from the *attributes* they aſcribe to it. For this fire is no dead image of a ſuperior intelligence in the Deity, but is aſſerted to be endued with an intelligence of its own; it is Πυρ νοερον, πυρ ζωηφορον, πυρ φαινον, ψυχη ουσα πατρος — αθανατος τε μενει, και ζωης δεσποτης εστι — *Intelligent fire, life-giving fire — ſplen-*

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* Inſerted in *Stanley*'s lives of the philoſophers, from *Franciſcus Patricius.*

† Αιθρης μελος, ηελιου τε, σεληνης τε, και οσα ηερι συνεχονται.

‡ Παντοτροφου αιθρης —— Ζωηφορον Πυρ.

did fire, the ſoul of the father, remaining immortal, and the Lord of life — which expreſſions are too high to admit of any thing ſuperior. You may indeed render νοερον by the word *intellectual*, which will give a different ſenſe; but from the whole tenor of theſe oracles, ſuch a conſtruction would be unwarrantable.

I hope I ſhall not ſtand in need of an apology, for wandering thus into the depths of the theology of the heathens, while I profeſſed only to collect their ſentiments on *natural philoſophy*. For it is conſpicuous enough, that philoſophy is here ſo metamorphoſed into divinity, that it is ſcarce poſſible for me to ſeparate them. With theſe unenlightened idolaters, wiſe enough as naturaliſts, but miſerably blind and ignorant of things ſpiritual, *God* and the *world* were but one and the ſame thing; and this perſuaſion gave birth to the whole ſcience of *aſtrology*, for which the *Chaldæans* were ſo much famed: ſo that if we deſire to obtain their judgment on *nature*, we are under a neceſſity of taking their theological doctrines along with it. I muſt therefore beg leave to go on a little farther upon the ſame plan, as there is ſomething in theſe remains of *Zoroaſter*, worthy of being brought out to the light.

HIS philoſophy included in it a kind of *phyſical trinity*, which is evidently made up of the powers of nature, and will ſerve to teach us, *what* he ſuppoſed theſe powers of nature to be, even the ſame as we have already found and eſtabliſhed from experiments: It was a principle of this philoſopher, that — Παντι εν κοσμω λαμπει Τριας, ης Μονας αρχει — *a triad ſhineth forth throughout the world, over which an unity preſides*. This *monad* or *unity* muſt ſignify the *ſun*; the *Aſſyrians* (that is, the *Chaldæans*) according to *Macrobius*, having worſhipped him under the name of *Adad*, which name, as he tells us, ſignifies *one* or *unity* *. As to the *triad*, I ſhould deſpair of unravelling ſo great a myſtery, had not another fragment of the ſame *Zoroaſter* preſerved its interpretation —

> ——— ιερος Πρωτος δρομος, εν δ' αρα μεσσω
> Ηεριος, τριτος αλλος ος ει Πυρι την χθονα θαλπει.

As theſe were undoubtedly deſigned for *hexameter* verſes, a word is plainly wanting at the beginning of the firſt line, which according to the ſenſe, the meaſure of the verſe, and the *poetic dialect* here made uſe of, muſt have been Ηελιȣ; † the ſenſe of the whole therefore is this — *The ſacred courſe of the ſun, or light, is the firſt power; in the middle there is an aerial power; and a third is that, which cheriſhes the world with fire.*

EXPERIENCE will teach us, that natural effects are immediately governed by theſe inſtruments of the divine power; and the ancients appear to have been well apprized of it. But what a miſerable uſe did they make of this valuable treaſure when they had got it! Here they ſtopt: this phyſical triad, by a ſtrange perverſeneſs and abuſe of reaſon, furniſhed them with a pretence for denying that ſupreme power, which gave birth to all things, and is of a nature independent and diſtinct from the world of matter.

ON the contrary, the fathers of the *chriſtian* church, having ſhaken off the prejudices of paganiſm, and being better informed by divine revelation, were always very ſevere upon the *Gentiles* for diſhonouring God by that vain philoſophy, which ſuppoſed him to be coequal and coeval with matter, a ſoul of the world, a *tertium quid* made up of matter and intelligence *. Among the reſt, *Epiphanius*, a learned and eloquent writer of the *fourth century*, has ſome remarks in this way upon the various ſects of the *Gentile* philoſophers †; and was ſo happy as to reſcue this *phyſical trinity* from the ethnic abuſes of it, and apply it to its proper uſe, as an emblem and ſhadow of the divine perſonality. Speaking of the coequality and *co-efficiency* of the *ſacred trinity* againſt ſome of the primitive heretics, he ſays — *Are not theſe three perſons to be underſtood by every one, as they are appoſitely revealed to us by light, fire, air; and, I think, by ſome other ſimilitudes alſo of viſible things, as man, whoſe underſtanding is thus miniſtred unto, is found worthy to receive them* ‡?

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* *Saturn.* lib. I. c. 23.

† Δρομȣς ηλιȣ is the phraſe uſed by *Hippocrates.* ſee p. 203.

As I have endeavoured, upon another occaſion, to give ſome proof, that my concern for this ſacred and fundamental doctrine of our religion is very ſincere, I could not help ſpeaking of this, as an hint to ground an argument, or rather an *illuſtration* upon from *nature*: and am perſuaded it might be improved, very much at large, to the entertainment and ſatisfaction of thoſe, who can take delight in ſo ſublime and deſerving a ſubject. But as I do not admire digreſſions, I muſt content myſelf at preſent with only propoſing it, as an article both ancient and curious; and leave a more particular proſecution of it, either to another hand, or at leaſt to another opportunity.

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* Quid enim aliud eſt *natura*, quam DEUS, & divina ratio toti mundo & partibus ejus inſerta? *Seneca* de Benef. lib. 4.

† *Epiphan.* Op. vol. I. p. 12. edit. Colon.

‡ Ουκουν τρια ταυτα οντα —— εκαστω αξιως νοουμενα, καθως εαυτα αποκαλυπτει φως, Πυρ, πνευμα· και αλλαις οιμαι ορατων ομοιωσεσι, καθως αξιος ο διακονουμενος ανθρωπος. *Id.* vol. I. p. 891.

CHAP. IV.

Some extracts from two authors among the Latins, Pliny *and* Seneca: *with ſome reflexions on the* Democritic *ſyſtem.*

AMONG the *Latins*, there are ſome pieces ſtill extant, which treat profeſſedly of nature; as the *natural hiſtory* of *Pliny*, and the *natural queſtions* of *Seneca*; the latter of which is the moſt compleat work of the kind, that is come down to us from antiquity.

PLINY was certainly no friend to a *vacuum*; he rather choſe to follow the judgment of earlier times, and underſtood the *heaven* and the *air* as two names for one and the ſame thing [*]. And leſt we ſhould miſtake his meaning, he ſubjoins, that every ſpace which *looks like a vacuum*, is in fact a promptuary of this element. The earth and the planets float in it, and are ſupported by the ſtrength of it: it paſſes through all things, and makes a part in the compoſition of all bodies [†].

HE relates it as the opinion of *Poſidonius*, the mathematical preceptor of *Cicero*, that the region of the winds, clouds, and vapours, is extended to about 40 *ſtadia* above the level of the earth's ſurface; and that thenceforward, throughout the higher regions, *there is a pure and liquid air*, *with an undiſturbed light* [‡]. It is worth remarking, that this ancient geometer hath fixed upon the altitude of 40 ſtadia (which make nearly 5 *Italian miles)* for the extent of the atmoſphere; this being the very quantity that comes out, if equal ſpaces in the atmoſpherical column ſhould correſpond to equal parts in the column of the barometer: whence it ſeems not improbable, that he was poſſeſſed of ſome experiment for diſcovering a counterpoiſe to the preſſure of the atmoſphere, though his inference from it was not ſo correct as it ought to have been.

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[*] *Cœlum* appellavere majores, quod alio nomine *aera:* omne quod inani ſimile vitalem hunc ſpiritum fundit. *Plin.* Nat. Hiſt. lib. 2. c. 38.

[†] *Ibid.* c. 5. & 6.

[‡] *Poſidonius* non minus quadraginta ſtadiorum a terrâ altitudinem eſſe, in quâ nubila ac venti nubeſque proveniant. Inde purum liquidumque & imperturbatæ lucis aerem. *Ibid.* c. 23.

In regard to *fire*, *Pliny* aſſures us, it had never been doubted, ſo far as he was able to find, that the elements are *four* in number, and that fire is one of them [*]. This fluid is preſent in the human body, in wood, in ſtone, and even in water itſelf. Nature is ſo repleniſhed with it, from the immenſe fire of the ſun and ſtars, clouds, burning mountains and fiery exhalations from the earth, that it ought to be eſteemed as the greateſt of miracles, that a ſingle day ſhould paſs without a general conflagration of the univerſe [†].

Another phyſical writer among the *Romans*, is *Seneca*; who aſſerts poſitively enough, that there is no ſuch thing as a vacuum in nature [‡]: that a medium muſt be concealed within the moſt *ſolid* bodies, becauſe *ſound* would not otherwiſe be *tranſmitted through them*, as it certainly is [**]. Some philoſophers would be objecting, that a bird could not fly through the air, unleſs there were a *vacuum between its par-*

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[*] *Ibid.* c. 5.

[†] *Excedit profecto omnia miracula, ullum diem fuiſſe, quo non cuncta conflagrarent.* Ibid. c. 107. ſee the whole chapter.

[‡] Nihil enim uſquam inane eſt. *Nat.* Quæſt. l. 3. c. 16.

[**] Vox autem quâ ratione per parietum munimenta tranſmittitur, niſi quod ſolido quoque aer ineſt. *Ibid.* l. 2. c. 9. This is one of *Du Hamel*'s arguments for a *ſubtil æther*, in favour of *Des-Cartes*; and more, I believe, might be ſaid upon it, than he was aware of.

ticles. Seneca affirms on the other hand, that the ſeveral parts in a line of matter cannot poſſibly affect one another without continuity [*], a poſition, which excludes the whole ſyſtem of immaterial attractions and repulſions: and that the continuity of water is no hindrance to a free motion of ſolid bodies in it; becauſe it is the nature of fluids to yield, and *flow backwards with a contrary motion into the ſpace deſerted by the moving body.* Upon which conſideration, there is no neceſſity for an *interſperſed vacuum* [†].

Of the *air*, and its influence as a phyſical cauſe, he ſpeaks nearly in as high a ſtrain as *Hippocrates* himſelf. He goes ſo far, as to impute the *coheſion of our bodies* to it, and therefore muſt undoubtedly have been acquainted with the preſſure of the atmoſphere, of which the ancients are ſuppoſed to have been altogether ignorant [‡]. Where the atmoſphere ends, it was his opinion, that a purer *æther* begins, and is extended from thence to the ſun and ſtars [||]. And laſtly, he held, that what is called *fire* occupies the whole world [††].

We ſee then, what hath been the general ſenſe and doctrine of the ancient philoſophers, concerning the operations of nature. When I had determined to conſult their judgment upon this important ſubject, I perceived it was neceſſary to confine myſelf to theſe few leading queſtions—*Whether they had found the world to be* full *or* empty *of matter? What* offices *they aſſigned to the different* elements, *of*

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[*] Nunquam enim contexti, *niſi per unitatem*, corporis niſus eſt; cum partes *conſentire* ad intentionem debent, & *conferre vires.* Lib. 2. c. 6.

[†] Aquarum quoque ſimilis facilitas eſt: nec de unitate illarum dubium eſt, quæ ſic corpora accipiunt, ut *ſemper in contrarium acceptis refluant ---- Nihil autem opus erit inani admiſſo.* Lib. 2. c. 7.

[‡] Eſſe autem unitatem in aere, vel ex hoc intelligi poteſt, *quod corpora noſtra inter ſe cohæreant.* Quid enim aliud eſt quod tenet ea, quam ſpiritus? *Ibid.* c. 6.

[||] Lib. 2. c. 14. lib. 1. c. 2.

[††] Dicimus autem ignem eſſe, qui occupet mundum. Lib. 3. c. 13.

which the material world conſiſts? And, *to what* cauſes *in ſpecial, they thought fit to aſcribe the immediate production of* natural effects? Had I not thus preſcribed to myſelf ſome certain limits, my enquiry had been both endleſs and unmeaning; and the deſign of the preſent work being ſuch, as to include only the *cauſes of motion*, or *firſt principles* of natural philoſophy, it would have been impertinent to have followed the ancients farther than I have done. The main ſubſtance of what I have extracted from them, agrees ſo well with what we had obtained before, by an examination of nature itſelf, that the *concluſion*, at the end of the preceding book, will never be ſuſpected of *novelty*, by thoſe who have had patience enough to follow me through the ſeveral articles of this collection; and ſome, perhaps, may be led by this courſe to entertain a better opinion of its *truth*.

BUT it now behoves me to confeſs, that the ancients have been applied to for their ſuffrage in behalf of ſome principles, widely different from thoſe, for which I have here been pleading. Dr. *Clarke*, in his ſecond reply to Mr. *Leibnitz*, thought proper to inſert the following obſervation — "Many "ancient *Greeks*, who had their philoſophy from the *Phœ*"*nicians*, and whoſe philoſophy was corrupted by *Epicurus*, "held in general *matter* and *vacuum*; but they knew not "how to apply thoſe principles by *mathematics* to the expli"cation of the *phœnomena of nature*." Who could theſe *Greeks* be? Neither *Pythagoras*, nor *Plato*, nor *Ocellus Lucanus*, nor *Thales*, nor *Zeno*, nor *Ariſtotle*, whoſe names were moſt ancient and famous in natural philoſophy, are found to have acknowleged theſe principles. But he that is aware of Dr. *Clarke*'s manner of repreſenting things, will not be ſurprized, when he diſcovers, that theſe *many ancient Greeks* were the *Democritic* atheiſts; who by the help of an internal power or *gravitating force* in *atoms*, and a *vacuum* wherein theſe atoms might have room enough to move without being reſiſted, had dextrouſly contrived to account, as well for the *formation* as the *preſervation* of the world, without a *divine providence.* If the cleareſt teſtimonies are of any weight, the brains of *Leucippus* and *Democritus* were firſt delivered of this philoſophy. Such as it is, you have a copious account of it in *Laertius*'s life of *Epicurus*, and in the poem of *Lucretius*; who, in defence of his *vacuum*, wiſely argues againſt a *fact*, becauſe he could not underſtand how that *ſhould* be, which really *is* *. This ſyſtem included ſome ſubtil ſpeculations, concerning the ſizes and figures of the firſt principles of bodies, and the appearances that may ariſe from them, which are not without their uſe: and hence the followers of it had the denomination of *Atomiſts*, or *Corpuſcularians*. This branch of their ſcheme was probably very ancient and of good authority, and has, I believe, been cultivated more or leſs by the philoſophers of every age. It was revived in a particular manner in the laſt century; and Mr. *Boyle*, to whom we are ſo greatly indebted, was very fond of ſolving effects from ſome certain configurations of the primitive particles of bodies. But how effects can ariſe, merely from a configuration of the parts of matter, I ſee not: and it ſeems as unreaſonable to form a ſolution wholly and altogether upon ſuch a ſpeculation, as to deduce the demolition of a fort from the *ſpherical figure* of a cannon-bullet; which indeed is of a form, fitted for its flight through the air, as it comprehends moſt weight under the leaſt ſurface; and of a ſize beſt adapted to the cylindrical cavity of the gun: but muſt remain inactive within it, till it receives motion from a proper agent, the conſideration of which is infinitely more important than the figure of the bullet, though that alſo is by no means to be neglected.

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* *Lucret.* lib. 1. l. 371. *Illud in his rebus*, &c.

THUS far the *Democritic* method of philoſophizing might be both ancient and innocent; but this, I preſume, was not the part upon which Dr. *Clarke* ſet a value, as he did not think it worth mentioning; nor could it indeed be of any ſervice to the argument he was upon. It recommended itſelf to his attention, by its doctrines of a *vacuum*, and an inherent quality of motion in the parts of matter; by which it differed from the beſt and moſt univerſal philoſophy of antiquity, and was diſtinguiſhed as a foundation for atheiſm.

THE derivation of its pedigree from *Phœnicia* is altogether groundleſs, and is ſufficiently refuted in what we have ſeen already; as alſo by what is affirmed of *Thales*, the *firſt* among the *Greeks* who travelled into that country in ſearch of natural philoſophy, and maintained, that *there is no ſuch thing as a vacuum in the world. Plutarch*, who informs us of this, adds upon the occaſion, that *all philoſophers, but the* Atomiſts, *who denied a providence, agreed in this doctrine**.

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* *De placit. philoſ.* I. 18.

CHAP. V.

The ſentiments of the moſt eminent of the modern *writers ſubjoined to thoſe of the* ancients.

SINCE the ſuppoſed diſcovery of a vacuum, ſome have confidently affirmed, that natural effects are no way to be accounted for, but by the power of the Deity immediately intereſted: and either the reaſon of man, or the reaſon of things, is ſo altered, that what did ſerve formerly as a ground-work to atheiſm, is now recommended as the only ſure foundation of natural religion; as if it were impoſſible for God to act by ſecondary cauſes, without tempting us to believe, that ſuch cauſes were able to contrive and frame a world without his interpoſition. Thoſe who object to ſecond cauſes, upon any pretenſions to religious motives, muſt imagine ſurely, that matter, if there is but enough of it, can move, act, and think, by its own nature. If it cannot, we are in no danger of excluding a divine power, by filling the heavens with a fluid medium: if we ſuſpect that it can, then we make ourſelves materialiſts, that is atheiſts, in order to confute atheiſm more effectually. So that this triumph of natural religion over atheiſm, is either affected, to ſerve ſome *hypotheſis*, or grounded upon too haſty a judgment of things.

AN infallible criterion of ſimple and abſolute atheiſm, is the excluſion of *final cauſes*. If you can fix upon two or three of theſe, which are clear and beyond diſpute, as that the *eye* does not ſee *by accident*, but was *contrived for ſeeing*, and ſuch like, you anſwer all the atheiſts that ever were or ever will be; who are no better than ſots and ideots, if they can ſtand out againſt the teſtimony of their own ſenſes. For you prove, by a ſingle ſtep of reaſoning, that there is a divine mind or wiſdom, that hath wrought with a view to certain *ends*, which it hath attained in the moſt perfect manner. This topic is well purſued by *Cicero*, in a beautiful and maſterly draught of the wiſdom and deſign that appears in the various works of the creation. It makes a conſiderable part of his ſecond book *de naturâ deorum:* and in my opinion, this diſcourſe, ſo far as it is a confutation of *atheiſm*, is abundantly ſufficient for that purpoſe, and compleat enough in its argument, without any farther additions.

But all this, though unexceptionable and unanſwerable, is obvious (as it ought to be) to every capacity; it is plain, eaſy, and old-faſhioned: therefore all men are not pleaſed with it. If you will follow their new preſcription, you muſt bring yourſelf, in the firſt place, to believe *a vacuum*; the ſteps to which are not underſtood by one in a thouſand: then you are to remove the notion of *actio in diſtans*, which in the laſt age had ſome great authorities on its ſide: then you arrive at this concluſion, though not without a conſiderable ſtride, that God himſelf is the ſole agent, to whoſe immediate power, excluſive of all ſecondary agents, the loweſt effects in the world are to be imputed. And if theſe things are ſo, then it follows, that there is a God, and you triumph over atheiſm. But in the mean time, if your foundations ſhould be weak, and experiment ſhould overthrow your arguments for a vacuum; the capital truth of natural religion, as you have contrived to ſtate the matter, will be in a very precarious ſituation. No good, therefore, can accrue to religion, from *this* method of confuting *atheiſm*; and ſome danger is always to be apprehended from new and empirical projects in divinity.

OF this the excellent Lord *Bacon* was truly ſenſible: and there is not, in the whole courſe of his writings, ſo heavy a cenſure, as that which he thought proper to paſs upon the error now before us. "Certain it is, (ſays he) that God worketh nothing in NATURE but by SECOND CAUSES: "and if they would have it otherwiſe believed, it is mere "*impoſture*, as it were in favour towards God; and nothing "elſe but to offer to the author of truth, the *unclean ſacrifice* of a *lie* *."

IT is obſerved by the ſame author, with that brightneſs of expreſſion, ſo familiar to him upon all occaſions, that "*heat* and *cold* are nature's two *hands*, whereby ſhe chiefly "*worketh* †." The nature of *cold* in particular, he propoſes as a thing worthy the inquiſition "both for uſe, and diſcloſure of CAUSES ‡." And he does not ſeem to have believed, that cold is a mere privation of ſubſtance; but rather, that it is "active, and tranſitive into bodies adjacent, as "well as heat **." *Gilbert*, the magnetic philoſopher, having poſſeſſed himſelf, as he thought, of an *attractio in diſtans*, had publiſhed the doctrine of an abſolute vacuum in the ſpaces between the celeſtial orbs. The Lord *Bacon*, on the other hand, had formed to himſelf "a theory, according to "which, all ſpace is *filled* either with an *aerial* or *fiery* "nature ††." He denied alſo, "that the pores or cavities "of tangible bodies admit of a vacuum; but that they

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* *Adv. of Learn.* p. 5.

† *Nat. Hiſt.* Cent. I. N°. 69.

‡ *Ibid.*

** *Ibid.*

†† Theoria noſtra negat vacuum illud coacervatum *Gilberti* inter globos ſparſos, ſed ſpatia vel *äereâ* vel *flammeâ* naturâ *repleri*. *Thema Cœli.*

" contain either *air*, or a ſubtil *ſpirit* proper to their nature " and diſpoſition *." Of this ſpirit he treats, as of a *material* cauſe; rejecting all thoſe pretended ſolutions, as unmeaning and unphiloſophical, which are deduced from *virtues* or *qualities* in matter, and with which the ſchools in his time did very much abound. " Whatſoever is inviſible (ſays he) " either in reſpect of the fineneſs of the body itſelf, or the " ſmallneſs of the parts, is but little enquired. And yet " theſe be the things that GOVERN NATURE princi-" pally; and without which, you cannot make any true " *analyſis* and indication of the *proceedings of nature*. The " ſpirits or *pneumaticals*, that are *in* all tangible bodies, are " ſcarce known. Sometimes they take them for vacuum; " whereas they are the moſt active of bodies. Sometimes " they take them for air; from which they differ as much " as wine from water. Sometimes they will have them to " be natural heat; whereas ſome of them are cold. And " ſometimes they will have them to be the *virtues* and *qua-" lities* of the tangible parts which they ſee; whereas they " are things by themſelves. And when they come to plants " and living creatures, they call them ſouls. And ſuch ſu-" perficial ſpeculations they have; like proſpectives, that " ſhew things inward, when they are but paintings. Nei-" ther is this a queſtion of *words*, but *infinitely material in " nature*. — As to the motions corporal, within the enclo-" ſures of bodies, whereby the *effects* paſs between the *ſpirits* " and the *tangible parts*, which are arefaction, colliqua-" tion, concoction, maturation &c. they are not at all hand-" led. But they are put off by the names of virtues, and

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* Nullum corpus, nobis notum hic in ſuperiore parte terræ, ſpiritu vacat ---- Neque enim cava rerum tangibilium vacuum recipiunt; ſed aut aerem, aut ſpiritum rei proprium. *Hiſt. Vit. & Mort.* Can. 2.

"natures, and actions, and paſſions, and ſuch other logical "words. — It is certain, that of all *powers* in nature, *heat* "is the chief; both in the *frame of nature*, and the *works* "*of art* *."

That Mr. *Boyle* was nearly of the ſame opinion with his great predeceſſor, and always ſearching for an explanation of effects from *ſecond cauſes*, muſt needs be known to thoſe who have looked into his philoſophical works, and in particular his *hiſtory of firmneſs*, where he attempts to derive even the coheſion of ſolids from the preſſure of the atmoſphere. For although he was unſucceſsful in this, it ſerves to teach us, what his general perſuaſion was: and the induſtry of man, ſtill working upon the ſame ground of ſecond cauſes, may in due time be productive of ſome better fruit.

Dr. *Cudworth*, author of the *intellectual ſyſtem*, is one of thoſe many writers, who have condemned that poſition, whereby God himſelf is made to be the ſole agent in nature, as improbable in itſelf, and unworthy of the Deity. As his arguments appear to me to be worthy of conſideration, I ſhall here adopt, and ſupport them with ſome farther obſervations of my own. Firſt then, this poſition *throws down all diſtinction between God and nature*, and turns every ordinary effect into a miracle. Then again, it is not conſiſtent with *that ſlow and gradual proceſs in the generation of things, which ſhews the agent not to be omnipotent*. A plant will advance in its growth, either more or leſs, as the ſeaſon happens to favour it: and if the heat and the air be withdrawn from it, it will not grow at all. Is it credible, that the divine power ſhould be baffled and overcome by theſe, or any other difficulties? Yet this, impious as it may ſound,

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[*] *Nat. Hiſt.* Cent. I. N°. 98. 99.

ſeems to be the neceſſary conſequence of ſuppoſing that power to act in ſuch a manner, as to ſuperſede the uſe of all natural inſtruments.

THE falſehood of this poſition is farther evident, from thoſe *errors* and *accidents*, whereby the formation of things is frequently interrupted. Theſe *argue the agent not to be irreſiſtible*; *and that* nature *is ſuch a thing*, *as is not altogether incapable of being ſometimes fruſtrated and diſappointed*, *by the indiſpoſition of matter* *. It is a common obſervation, that branches of trees, particularly of the aſh, will grow out of their legitimate ſhape, and become flat or faſciated. The ingenious Mr. *Hogarth* has introduced the figure of a curious ſpecimen of this ſort into his *analyſis of beauty*; where even the aberration of natural cauſes from their proper ſcope, appears to be productive of the greateſt elegance, but without utility. The like will ſometimes happen to a ſtalk of *aſparagus*, if the ſoil is too ſtubborn, or a ſtone lying in the way, chances to divert the growth of it. And many other inſtances muſt occur to thoſe, who employ themſelves in inſpecting the operations of nature.

IT is ſurprizing to ſee, what varieties of figure, ſtructure, and colour, are made to ariſe in vegetables, merely through ſome change, either in the efficient cauſes of vegetation, or the nature and diſpoſition of the materials they have to work upon. Two wild plants of the ſame ſpecies ſhall be found with leaves of very different figures, only by growing many miles aſunder, where there is ſome difference in the air and in the ſoil. And there are plants, which cannot be kept alive but in their native air, how inclement ſoever it be; of which we have one example in that large *yellow violet*, ſo common upon the higheſt and moſt weſterly mountains of *Derbyſhire.*

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* *Intellectual ſyſtem.* Book I. cap. 3. §. 4 &c.

Those who follow the method of *Linnæus*, and diſtinguiſh herbs into claſſes from the various characters in their organs of generation, muſt have had many opportunities of obſerving ſome confuſion in the *number* of their *ſtamina*; ſo that it is ſometimes difficult for thoſe, who are novices in the art, to determine to which of his claſſes a plant ought to be referred.

By the arts of cultivation, common among gardeners, the beauty of a plant may be greatly increaſed *at the expence of its fructification:* for the doubling of the flower obliterates the rudiments of the ſeed-veſſel, and defeats one end of its being, by rendering the plant incapable of propagating its ſpecies by ſeed. This is ſometimes obſerved to happen, even while plants are left to themſelves in their native places. To theſe we may add all thoſe plants, which being brought into *England* from countries nearer to the ſun, are never *compleatly formed* in this climate; being always barren and without ſeed, unleſs they are aſſiſted with hot-beds and ſtoves: and many there are, which even with theſe helps, cannot be brought to any degree of perfection.

The richneſs of the ground will very frequently occaſion ſome unexpected appearance in plants that are moved into it from a barren ſoil. The *Herba Paris*, a vegetable of a ſingular ſtructure, (ſee plate III. fig. 4.) is always found with *four leaves*, as it grows wild in the woods. And this form is ſo general to the individuals of the ſpecies, that in its ſeveral names, a particular regard is always paid to this quaternity of its leaves: *Moriſon* calls it, *ſolano congener non ramoſum tetraphyllum.* C. Bauhine, *ſolanum bacciferum quadrifolium:* and to thoſe who impoſed the name *Paris* upon it, I imagine, its four leaves regularly ſurrounding the ſtalk, and the ſingle round berry at the top of it, ſuggeſted an idea of *Paris* and the *three goddeſſes*, with the *apple* of contention in the midſt of them. Yet this herb will depart from its natural form, if it is removed into the richer ſoil of a garden, and bear *ſix* leaves, inſtead of *four*. I have tried the experiment, and have ſuch a ſpecimen in my poſſeſſion.

THESE things I thought it worth the while to ſpeak of, as ſo many effects, which cannot with any ſhew of reaſon or piety be aſcribed to the power of the deity immediately intereſted. It is therefore moſt agreeable to religion, reaſon, and experience, to conclude with Dr. *Cudworth*, that there are agents or inſtruments in the world, whoſe powers being only of a ſubordinate kind, may by certain circumſtances be made to vary in their effects, ſo as to go faſter or ſlower, like a clock with different weights applied to it; and to be even *fruſtrated and diſappointed in their operations by the indiſpoſition of matter*. The *wiſdom* of God will alſo be infinitely magnified, if he is found to bring about thoſe things by the mechaniſm of ſecond cauſes, to which philoſophers have determined the divine power itſelf to be abſolutely neceſſary. And we may hence derive the only rational encouragement to a chearful and diligent ſtudy of nature. The cauſes employed are few and ſimple beyond expreſſion: their effects are infinitely various and wonderful; and to thoſe who begin upon a right foundation, they will unfold themſelves every day more and more; nor will the labour of man be loſt in the purſuit, till he has acquired as much knowlege of this ſort as will do him any good in his preſent ſtate.

In the judgment of that eminent experimentaliſt Dr. *Boerhaave*, "ſo great is the power, ſo extenſive the action, and ſo "wonderful the manner wherein *fire* acts; that it was anciently held and adored as the ſupreme God, by a nation reputed the wiſeſt of all others. Thus ſome of the chemiſts, "having found its extraordinary force, took it for an uncreated "being; and many of the moſt eminent among them, attributing all the knowlege they had acquired to this INSTRUMENT, called themſelves *philoſophers of fire*; as thinking they could not be dignified by an higher title. There "is however nothing more wonderful in the nature of fire, "than that while it is the chief CAUSE and PRINCIPLE "of almoſt all the effects cognizable by our ſenſes, yet itſelf is imperceptible by any ſenſe; being ſo incomprehenſible, by reaſon of its extreme minuteneſs, that it eludes "our niceſt reſearch; ſo that with many, it paſſes for a "ſpirit rather than a body [*]." That the world ſhould be ſo full of this fluid, and we ſhould be ſo little ſenſible of it, is indeed very aſtoniſhing. But the wonder wholly ceaſes with thoſe, who argue, upon this account, that there is no ſuch thing: that if there were a plenum of ſubtil æther round about us, we ought to move with as much trouble, as if we were wading through an ocean of mercury. Now if you were to tell an ignorant man, that if the greateſt diameter of the trunk of his body is equal to 15 inches, he is preſſed downwards to the earth by a weight of more than three thouſand pounds; he would hardly believe you; but would argue, that, in ſuch a caſe, he ought to be cruſhed to death; whereas he moves eaſily, and feels no impediment. Yet this is known to be unqueſtionably true, by thoſe who underſtand the *barometer*, or have ſeen any experiments with an *air-pump*. And what is ſtill more ſurprizing, there is another agent, every where preſent, a column of which, equal only to an ordinary needle in diameter, when in motion through the body, ſhall make you ſenſible of as great a force, as if you had received a blow upon the arms with a ſledge-hammer; and the muſcles of the ſtrongeſt man in the world can do nothing againſt it. How does it happen, that we can paſs a ſingle day without being ſhattered to pieces? For if ſo minute a column can exert ſo terrible a force, what are we to expect from a column that has the whole body for its baſe? The reaſon that we feel no harm is this; that force is every way oppoſed to force; and none of it is perceived, while the *equilibrium* is preſerved. When that is by any means interrupted, an unexpected force immediately diſcovers itſelf. We ſhew but little experience of nature, and as little gratitude to the author of it, if we diſpute againſt the reality of a ſubtil medium, becauſe our lives are not rendered miſerable by the force of it. For God, with equal wiſdom and goodneſs, hath put both our bodies and this matter into a mechaniſed ſtate, ſo that it ſhall do us all the good that is required, without ſtanding in the way to do us miſchief. And this matter is what Dr. *Boerhaave* meant to ſpeak of under the name of *fire*.

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[*] *Boerhaave*'s chemiſtry, by *Shaw*. Vol. I. p. 206.

THE element of *air* is deſcribed by the ſame author, as "an univerſal, neceſſary, and moſt efficacious *inſtrument*, "which nature is perpetually applying in almoſt all her "works*." Experiments, as he ingenuouſly confeſſes, often led him to conſider, "whether God did not originally create "fire, and pure elaſtic air, *and diſtribute them through the* "*whole univerſe* †."

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* *Ibid:* p. 381. † *Ibid.* p. 420.

To theſe authorities, let me add that of Dr. *Berkeley*, the late excellent and univerſally-learned biſhop of *Cloyne*, whoſe opinion may be learnt from the following extract — "Without inſtrumental and ſecond cauſes, there could be no "regular courſe of nature; and without a regular courſe, "nature could never be underſtood. The order and courſe "of things, and the experiments we daily make, ſhew there "is a mind that governs and actuates this mundane ſyſtem, "as the proper real agent and cauſe; and that the inferior "*inſtrumental cauſe* is pure æther, fire, or the ſubſtance of "light; than which, it doth not ſeem neceſſary from phœ"nomena, to ſuppoſe any medium more active and ſubtil. "As for *attraction*, it cannot produce, and in that ſenſe ac"count for the phœnomena, being itſelf one of the phœno"mena produced, and to be accounted for. What is ſaid "of forces reſiding in bodies, whether attracting or repel"ling, is to be regarded only as a mathematical hypotheſis, "and not as any thing really exiſting in nature *."

THE *Abbè le Pluche*, whoſe ingenious and ſpirited writings will give both pleaſure and improvement to every reader, appears by his productions to have laid in a large ſtock of experimental knowlege, with a competent degree of ſkill in mathematical learning. He has taken a liberty of following nature and obſervation, as a philoſopher at large, not devoted to any ſect or ſyſtem: and his enquiries, it ſeems, have led him to this concluſion; that "there are but three "known fluids in nature, which by their continual activity "are the *principles of all motion*; and theſe are, *light*, *fire*, "and *air* †." How preciſely does this paſſage coincide with

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[*] Siris. *Art.* 160. 154. 243. 234.

[†] *Spectacle de la Nat.* Vol. 4. Diſc. 12. p. 119. of the *Engliſh* tranſlation.

the judgment of antiquity! The principle that was maintained as the fundamental truth in phyſics, above two thouſand years ago, by *Zoroaſter* and *Plato*, diſcovers itſelf again, at this diſtance of time, to a naturaliſt who enquires in a proper manner. This coincidence would have happened oftener than it has, if philoſophers had conducted themſelves as the ſcholars of nature, and not as its maſters. For nature is the ſame now, as it was then; and experiment, duly conſulted, would ſpeak the ſame language in all ages. The fault is in men; who by affecting to ſurprize the world with building things high and marvellous after a model of their own framing, fall into confuſion and ſelf-contradiction; while they overlook what is truly valuable, becauſe it is cheap, and common, and hath not an air of myſtery and darkneſs ſcientific.

The concluſion of this celebrated author might, I think, be deduced from premiſes very plain and obvious without any aſſiſtance from *Algebra*, *Geometry*, *Greek*, *Latin*, or *Hebrew*. For what ſcholarſhip doth it require, to be able to diſtinguiſh, that *light* gives ſight to the eyes? that *air* is the breath of life? and that without *fire* or heat applied in its proper degree, the blood is congealed, and the limbs are inflexible? All this is evident to the moſt undiſciplined apprehenſion: for a man is no ſooner born into the world, than he makes moſt of the experiments requiſite for the obtaining of this knowlege; and he may challenge the moſt ſubtle philoſopher, to name that ſubſtance or fluid in the whole univerſe, which can ſupply the place of any one of theſe. What then can be plainer, than that theſe, as the *Abbè le Pluche* hath rightly affirmed, are the phyſical *principles of all motion?* And where can the naturaliſt employ his labour to ſo much advantage, as in deriving effects from theſe cauſes? For although they are obvious to the vulgar in many of their operations, the moſt able diſquiſitor might purſue them for a thouſand years, and find after all, that he had left a great deal of matter untouched.

THE phœnomena of *light* were cultivated with equal induſtry and ſagacity by Sir *Iſaac Newton*: and what a ſcene does this fluid furniſh out to a contemplative mind, by the glorious variety of its colours, the amazing velocity of its motion, its reflexions, refractions, and the inconceivable ſubtilty of its ſubſtance! After it had been examined and re-examined by this great geometrician for many years: and after the ſpeculum of *Villette* had ſurprized the world, with the effects of the ſolar rays upon bodies expoſed to the focal heat of it; *electricity* broke in upon us, as it were by accident; began a new epocha of philoſophy, and diſcovered light to be a moſt powerful and univerſal cauſe of motion, with which the whole world is filled; opening to us a freſh ſtorehouſe of effects, as inexhauſtible as the ſcience of optics.

MANY effects of the *air* are ſo common, and withal ſo very important, as to be taken notice of by every writer on natural philoſophy. It is plainly acknowleged as a material cauſe of motion, by thoſe who imagine they get rid of ſuch things, if they can but exclude *the air* from a glaſs receiver. Many things curious and ſurpriſing occurred to Dr. *Hales*, when he undertook to analyze this element; and he diſcovered, what others appear to have known many ages before, that it makes a part in the compoſition of all bodies; which derive their activity from this ſubſtance, ſo artificially combined with them for that purpoſe.

WITH the wonders that preſent themſelves to us in a natural hiſtory of *fire*, any reader may become acquainted, by peruſing Dr. *Boerhaave*'s incomparable diſcourſe upon that ſubject. The ſeries of well-choſen experiments there laid down, will open to him many of the powers and uſes of that element, both in nature and art, and juſtify the higheſt expreſſions uſed by that learned chemiſt in the praiſe of it.

OF theſe *principles* much is already known; more than enough to reward the labour that is ſpent in ſearching after it. That much more yet remains to be known, I am induced to believe upon many conſiderations; and upon this amongſt the reſt: that ſome eminent men of late years, who have been beſt qualified to make diſcoveries and improvements, have been unhappily pre-engaged to ſchemes of another kind; and inſtead of cultivating the knowlege of theſe fluids, as the natural principles of motion, which is the light wherein they ought to be underſtood, have regarded all material inſtruments as the common enemy, becauſe hurtful and deſtructive to their ſyſtematical *vacuum*: and if any ſuch thing has diſcovered itſelf to them in their reſearches, it has either been ſtrangled in the birth, or repreſented as an underling to the old ghoſtly principles of *attraction* and *repulſe*; which have no meaning in themſelves, and do effectually ſhut the door againſt all farther advancement. If I wiſh that thoſe who are fond of natural philoſophy may ſhake off theſe prejudices, it is only with this view — that their labours in that delightful ſtudy, may be attended with more pleaſure to themſelves, and profit to the publick.

CHAP. VI.

The judgment of the holy ſcripture *concerning the ſyſtem of Nature.*

THE mind of that man, who conceives ſo falſely of the divine oracles, as to believe that they maintain any oppoſition to true and uſeful learning, hath been debauched by ſome ſophiſtical reaſonings, or debaſed by groveling and unworthy purſuits. They arm us indeed againſt *vain* philoſophy, and all the empty fictions of the human imagination, which bring forth neither pleaſure nor profit to thoſe who are occupied therein. But then they invite us, in the ſublimeſt ſtrains, to conſider the *works of God*, whoſe counſels and perfections, as they are diſplayed in the creatures, will ever be beſt underſtood by thoſe who ſtudy *them* with humility and attention. Learning and philoſophy did never ſhine more bright, than when they met together with faith and religion in the mind of the excellent Lord *Bacon* *; whoſe opinion it was, that the wonderful works of God do *miniſter a ſingular help and preſervative againſt unbelief and error*. If there are any philoſophers ſo void of underſtanding, as to regard the ſcience of nature, only as a tower of ſtate for a proud mind to raiſe itſelf upon; and to eſteem themſelves as licentiates in incredulity, becauſe they make ſome figure in philoſophy; it may poſſibly do them good to look back upon the example of this great man, who preſerved a mind untainted with the pride of hereſy or infidelity; and was not more to be admired for his extenſive learning and experience of nature, than for his theological ſkill, and penetration into the wiſdom of the ſacred writings. "Two books or volumes of ſtudy (ſaith he) are laid "before us, if we will be ſecured from error: firſt, the "ſcriptures, revealing the will of God; and then the crea-"tures expreſſing his power, whereof the latter is a key un-"to the former *." Theſe two volumes being ſo nearly related, I ſhall conclude this treatiſe with a ſhort and humble enquiry into the judgment of the holy ſcripture; which the all-wiſe author of it hath ſo adapted to the exigences of man in his preſent ſtate, that the information it occaſionally gives us, concerning the viſible works of God, will warm and improve the hearts of the moſt ſimple, while it conveys light alſo to the underſtandings of the moſt learned.

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* If the reader deſires to have a taſte of the Lord *Bacon*'s character, from ſome piece, wherein the *chriſtian* and the *philoſopher* are united; I would recommend his *new atlantis*; a diſcourſe, which ſeems to have given the firſt hint for the eſtabliſhing of philoſophical academies in *Europe*, ſuch as is the *royal ſociety* of *London*, &c.

1. In the firſt place then we are taught, that the ſame God, who created the world in wiſdom, *upholds* † it in mercy; that in him we live and move and have our being. If the ſun gives us light and warmth, it is *his ſun*, which he *maketh to riſe* on the evil and on the good. If the clouds pour down their water upon our fields, to nouriſh and bring forward the fruits of the earth; it is he that *ſendeth rain* on the juſt and on the unjuſt ‡. To him, therefore, the bleſſings that are diſpenſed to us, in the ordinary courſe of nature, are to be devoutly aſcribed, as to the primary ſource of all life and motion. And this concluſion will be equally

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* *Adv. of learn.* B. 1.

† *Hebr.* 1. 3.

‡ *Mat.* 5. 45.

true, whether God is ſuppoſed to diſtribute the benefits of nature from his own hand immediately, or by the mediation of ſome ſecondary cauſes of his own appointing; for, either way, the real government of the whole can terminate only in himſelf.

2. SOME will diſpute againſt the operation of ſecond cauſes, as thinking it to derogate from the *power* of God, that he ſhould *ſtand in need* of their *aſſiſtance*. But they ſhould remember, that God did not make the world becauſe he himſelf ſtood in need of any thing: it was for his own good pleaſure, and the benefit of his creatures: and with the ſame views he eſtabliſhed the operations of ſecond cauſes; he conſulted *our* wants in this matter, and not his own. For man is a compounded being, made up of different parts, that claim a kindred with two different worlds, the viſible, and the inviſible. The part in him, which is natural or bodily, muſt be ſupported by natural powers: the ſuperior or ſpiritual part, by God *who is a ſpirit*, and whoſe powers alone can poſſibly extend to the wants of it. When nature ſhall ſink, and the ſpiritual world open upon us, God himſelf will then take the place of all inferior cauſes*; and even under the preſent ſtate of things, a ſpiritual interpoſition is not wanting in the *chriſtian* diſpenſation: but then it is calculated for the benefit of man's *ſpirit*; while his body is ſtill left to the ways of nature. To miſrepreſent the divine power and eſſence as a *phyſical* agent, is to confound the two kingdoms of nature and grace; which, as two parallel lines, follow a like courſe, but can never be made to touch; and to loſe ſight of that great and beautiful diſtinction, an adequate underſtanding of which, in all its branches, would be the conſummation of human knowlege.

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* See *Rev.* 21. 23.

3. THE government of nature then, by *ſecond cauſes*, is moſt ſuitable to the real *fitneſs of things*. It is the courſe God hath thought proper to fix upon, as ſerving beſt to his own glory and our good. Experience ſhews it; antiquity confirms it; and the ſcripture alſo, without condeſcending to treat of it minutely as of a ſcience, hath declared it in ſuch language, as cannot be made to ſpeak any other ſenſe without art or violence. That this matter may be brought to a ſhort iſſue, it will be proper to have in view thoſe *queſtions* above-mentioned ‡, by means of which I kept myſelf within a tolerable compaſs, when I collected the doctrine of profane antiquity. And firſt, let us aſk with all ſubmiſſion, whether the world, according to the ſacred account, *is full or empty of matter*.

4. WE have learnt from *Pliny*, that it was a cuſtom with the ancients, to give the name of *heaven* to the elements that fill the heaven — *Cœlum appellavere majores, quod alio nomine, aera:* and again, *quid eſſe mirabilius poteſt aquis* in cœlo *ſtantibus?* meaning the *clouds* ſupported by the *air* *. *Cicero* has a like obſervation concerning the element of fire — *Ardor cœleſtis, qui* æther, *vel* cœlum *nominatur* †. Who then will be ſurprized, if the ſcripture, the undoubted ſource and original of the heathen coſmogonies, and the moſt ancient book in the world, ſhould be found to ſpeak in the ſtyle of antiquity? And certain it is, that by the word *firmament*, which occurs ſo frequently, and by the *heavens*, when that word is ſpoken in a phyſical ſenſe, thoſe *elements* are to be underſtood, which are diſtributed throughout the heavens. For the heavens are hiſtorically treated of as a part of the works of God; and it would be repugnant to truth, that

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* Lib. 31. c. 1.

† *Cic.* de Nat. Deor. lib. 2. c. 15.

‡ See page 214.

what is nothing in itſelf but empty ſpace, ſhould be declared to have been *made* and *finiſhed* *. It may indeed be objected, that by heaven is meant the viſible furniture of the heaven, the orbs of the ſun, moon, and ſtars: but this could never be the deſign of the hiſtory, becauſe the *hoſt of heaven* is mentioned apart, and diſtinguiſhed from the heaven itſelf.

5. From the new teſtament we learn — that *the heavens being on fire ſhall be diſſolved, and the elements ſhall melt with fervent heat* †. Whence it follows, firſt, that the *heavens* are *material*; they could not otherwiſe be ſet *on fire.* Secondly, that they conſiſt of *elements* capable of a *diſſolution*; for the terreſtrial elements are not here to be underſtood, the *earth alſo, and the works that are therein*, being mentioned immediately after. And thirdly, that the conflagration of the great day ſhall be brought on, by a total converſion of the ætherial matter into a devouring *fire:* a tradition of which went abroad into the world very early. It was taken up as a main article of philoſophy by the *Stoicks*; and ſeems not to be improbable in the eye of reaſon, as it paſſed for the *greateſt of miracles* with an *heathen* ‡, that this univerſal conflagration had not happened already; conſidering how abundantly nature is furniſhed with the materials for ſuch a cataſtrophe.

6. This *ſubſtantiality* of the heavens is farther confirmed, from the uſe and meaning of the word *firmament*, which is ſynonymous with that of *heaven.* There is indeed a vulgar doctrine, ſuch as might accord well with the genius of monkiſh expoſitors in the dark ages, when the ſolid orbs of *Ariſtotle* were in faſhion, that the *firmament*, ſpoken

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* *Gen.* 2. 1. 4.

† 2 *Pet.* 3. 12.

‡ See p. 213.

of in the ſcripture, ſignifies a kind of ſolid arch, or encloſure of the world, like a cieling; in which the ſtars are placed, as ſo many braſs nails, ſtuck upon the inner ſurface of an hollow ſphere. The futility and falſehood of which will appear from the application of this term. For the ſun, moon, and ſtars, are ſaid to have been ſet *in the firmament*: and no ſyſtem did ever yet aſſign the ſame ſphere to all theſe bodies, becauſe our ſenſes muſt aſſure us of the contrary. What can follow then, but that the firmament is a medium, extended from the region of the fixt ſtars, to the places of the ſun and moon? It is farther ſaid, that *fowls*, called in other places of the ſcripture the *fowls of the air*, and the *fowls of heaven* (which expreſſions being compared, will ſhew us, by the way, that the *heaven* and the *air* are one thing in the language of the ſcripture) fly *in* or *upon* this firmament [*]. Therefore, it is extended all the way from the earth, through the regions of the atmoſphere, in which the fowls fly, to the ſun and moon, and from thence to the fixt ſtars and beyond. The margin of our *Engliſh* verſion has the word *expanſion* inſtead of *firmament*; by which, as the moſt rational expoſitors agree, the *expanded æther*, or *diffuſed body of the air* is to be underſtood. And it was well obſerved by *Grotius*, that the *Chaldee* paraphraſt upon thoſe words of the 19th Pſalm — *the firmament ſheweth his handy work* — gives this interpretation — *they who conſider the* air, *will tell of the handy work of God.* It is farther remarkable, that *Plato* uſes the *Greek* word Τασις in the ſame ſenſe; of which *Serranus* obſerves — *quod quidem vocabulum* aeris *naturæ ſignificandæ accommodatum eſt* [†]. Theſe ſhort hints are ſufficient to prove, that a *vacuum* in the *heavens* is not more oppoſite to nature and experiment, than to the moſt ſimple declarations of the old and new teſtaments. It may occur as a collateral argument, to thoſe who ſtudy the oriental languages, that the bible has no word in the original to denote *ſpace*, as diſtinct from body; having expreſſed it by the word that ſignifies *air* *.

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[*] *Gen.* 1. 20.

[†] See his preface to the *Timæus*. Vol. 3. p. 11.

7. But we are now to aſk another queſtion; whether God, in his government of the natural world, acts by his *immediate power*, or makes uſe of *matter* as his *inſtrument?* The anſwer, I ſhould think, might follow naturally as an inference from what we have heard already. For if the *heavens* conſiſt of *expanded æther*, this ſubſtance muſt either ſtop the motion of the heavenly bodies, as the mathematicians, if we will underſtand the thing in their way, have very well demonſtrated; or be inſtrumental to the conſervation of it. And as the former part of this alternative is falſe by obſervation; the latter part of it muſt be true; whether we are able or not to inveſtigate and aſſign ſuch a mode of operation to the matter of the heavens, as ſhall ſtand the teſt of a ſevere examination.

8. That matter is *inſtrumental* in the hands of God, for the bringing to paſs his purpoſes in nature, is at leaſt to be ſuſpected, from what happened in the beginning of the creation. It could not be without ſome good and ſufficient reaſon, that motion was *firſt* impreſſed upon the celeſtial elements of light and air. If theſe were to be inſtrumental in the formation of other things, as experiment ſhews them to be now, the reaſon is plain in itſelf, and worthy of an inſpired hiſtorian. And then, even the order and proceſs, that is obſerved in the ſacred hiſtory of the creation, will

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* *Gen.* 32. 16.

ſuggeſt to us, what may be gathered in a more direct manner from ſome other places of the ſcripture. For there are expreſſions, which allude to and acknowlege an efficacy of the heavens upon inferior things. The *powers* of the heaven, which are to be *ſhaken*[*] in the laſt day, muſt ſignify thoſe natural powers, or material forces of the heavens, by which the viſible world is now ſupported and moved in a regular manner, according to the laws of nature; and not any inviſible *powers of the world to come*; becauſe they are mentioned with the ſun, moon, and ſtars, the other members of created nature. There was, it ſeems, a fit occaſion to make an exhibition of theſe natural powers, when the apoſtles were to be indued with inviſible *power from on high* upon the day of pentecoſt: that power having been communicated under the external ſigns of a *mighty wind* and *flames of fire*; to which two elements, men of all ages and nations, as it were with one voice, have aſcribed the powers of moving and governing the natural world. And if they were right in this, it is not ſtrange, that theſe ſhould have been fixed upon, as the fitteſt and moſt inſtructive emblems of inviſible power. In the book of *Job*, which, to ſuch a reader as the Lord *Bacon*, appeared *pregnant and ſwelling with natural philoſophy*[†], the *heavens* are affirmed by plain inference, to have a *dominion in the earth*[‡]. A queſtion is put to *Job* by the maker of the world, whether he was able to fix this dominion by any power or wiſdom of his own; which does neceſſarily imply, that ſuch a dominion is really fixed by the power and wiſdom of God. Looſe-thinking and ignorant readers of ſcripture may deſpiſe the philoſophy of the paſſages I have hitherto mentioned: but thoſe who examine the works of God without prepoſſeſſion, will ſoon diſcover by experience, that although they are very ſhort, they contain the ſeeds of much knowlege; the moſt obvious ſenſe that can be gathered from them, being ſuch as agrees beſt with all the experiments we are able to make.

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[*] *Matt.* 24. 29.

[†] *Adv. of Learn.* B. 1.

[‡] *Job.* 38. 33.

9. THAT matter is employed as an inſtrument in the hands of God, is farther evident, in that he made a miſt or exhalation to ariſe from the earth, for the growth of vegetables, even at their firſt formation *. When the waters of the flood were to be carried off, he made *a wind to paſs over the earth* †. When the plagues of *Egypt* were inflicted, a *wind* brought the locuſts; and another wind drove them away ‡. When the Red Sea was divided, the waters were made to go back by *a ſtrong eaſt wind*, which parted the waves, and laid the bottom dry, for the paſſage of the *Iſraelites* **. But theſe, it may be ſaid, were *extraordinary* occaſions: and I am not unmindful of it; as they are ſo much the more to my purpoſe on that very account: for thence it appears, that even upon ſuch occaſions, where the caſe will admit of it, God prefers the method of bringing his purpoſes to paſs by *natural means:* after which, it would ſurely be unreaſonable and abſurd, to deny the uſe of ſuch means in the *ordinary* courſe of nature. And the ſcripture itſelf will agree with us in this concluſion. For when the *ſun* is ſaid to RULE over the day, and to have been made for this end, what can we underſtand by it, but that he acts as a vicegerent; and is inveſted with a mechanical power of giving light, life, and motion, to ſuch objects as are ordained to receive his impreſſions? All nature revives, and puts on a new face, when he approaches nearer to us in

* *Gen.* 2. 6. † *Ib.* ch. 8. 1. ‡ *Exod.* 10. v. 13. 19.
** *Ibid.* 14. 21.

the ſpring; and ſinks into a temporary death, at his departure from us in the winter. That he acts in a mechanical manner, is alſo certain; becauſe a chain of matter is continued all the way from the agent to the object. His power conſiſts not in any immaterial quality, becauſe it obſerves the ſame geometrical law with the diffuſion of his light; and his efficacy upon the productions of the earth is greateſt, when the greateſt angle is formed between the horizon and his *rays*; though the ſolid ſubſtance of his body is then moſt remote from us, as the aſtronomers very well know. A good teleſcope will ſhew us, what changes are produced in the refraction of the atmoſphere, and what a tumult ariſes in the air from the agitation of the ſun-beams in the heat of the noon-day. The heaven ſeems tranſparent and undiſturbed to the naked eye; while a ſtorm is raiſed in the air by the impulſes of the light, not unlike what is raiſed in the waters of the ſea, by the impetuoſity of the wind. It increaſes with the altitude of the ſun; and when the evening comes on, it ſubſides almoſt into a calm. A ſight this, both edifying and inſtructive; and ſuch as we ought not to behold, without calling to mind thoſe words of the devout ſon of *Sirach* — *The ſun when it appeareth, declareth at his riſing a marvellous INSTRUMENT, the work of the Moſt High*[*]*!*

10. CAN it be thought now, that God performs thoſe things by *immediate* power, which, as we can ſee and feel, do follow the courſe of the ſun, and are performed by *his* mediation? Philoſophers who contend ſo eagerly for the immediate influence of a divine power *in nature*, ſhould blot this luminary out of the heavens; and their arguments

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[*] *Eccluſ.* 43. 2.

would have a little more weight. God hath reſerved to *himſelf* an office more ſuitable to his nature, than the office they have thought proper to aſſign him; even that of giving life, light, and knowlege to the mind or ſpirit of man. As to the light of the body, that and all the wonderful effects of it, are plainly adminiſtred to us by the ſun, as by an engine or miniſter ſubſervient to the purpoſes of its creator. But ſome there are, ſo unhappy as to miſtake the œconomy of God, both in the *natural* and *moral* world. If you will take their judgment, God, as a natural ruler, is to have the taſk of moving thoſe portions of matter, which are moved and ruled by the ſun, the work of his hands: while man is to aſſume the office of the *father of ſpirits*, and adminiſter light to his own underſtanding. In *religion*, which is the province of the Deity, and where there is a *dignus vindice nodus*, all is to be *natural*; but in nature, all effects are to be miraculous! Thus wretchedly will men reaſon, when they think philoſophy hath advanced them into a ſphere, ſuperior to the un-philoſophizing ſimplicity and truth of divine revelation.

11. THAT we may learn, once for all, what *ſpecies* of ſolution is authorized by the ſcripture; it will be beſt to fix upon ſome particular inſtance: and there is none more proper than that of *vegetation.* The *earth* is ſaid to *bring forth graſs:* this is the *effect.* The firſt cauſe of it, is the power of God, to whom all things owe their being, and by whom all things conſiſt: for *he cauſeth the graſs to grow for the cattle and herb for the ſervice of man* *. But then it is alſo ſaid, that *the tender graſs ſpringeth out of the earth, by clear ſhining after rain* †. Therefore God is the primary

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* *Pſal.* 104. 14.

† 2 *Sam.* 23. 24.

cauſe; the ſun is the inſtrumental cauſe; while the earth, ſoftened and diſſolved by the drops of rain, ſupplies the materials. This account, plain and ſimple as it is, gives us the out-lines of all that can be ſaid upon the ſubject, and guards us againſt every fundamental error. It condemns the impiety of the heathen idolater, by referring the whole glory of the work to a power ſuperior to matter: corrects the well-meaning ignorance of the philoſopher, who would confute atheiſts, by evacuating the world of ſecond cauſes: and leaves us in poſſeſſion of that ancient and valuable doctrine, that ſome of the elements are appointed to rule over, and give motion to the reſt.

THE END.

A
POSTSCRIPT
CONTAINING
THE AUTHOR'S REMARKS ON SOME PASSAGES OF THE FOREGOING WORK.

On Book I. Chap. III.

PAGE 28. *line* 11 &c. To underſtand the objection which the author endeavours to obviate in this place, it is neceſſary to have ſome little knowlege of the *theory of falling bodies.* For the ſake, therefore, of ſuch readers as have not conſidered this ſubject, and to ſave them the trouble of having recourſe to other books, I ſhall here ſubjoin an account of it, and try to make it eaſy to thoſe, who have never accuſtomed themſelves to mathematical reaſonings.

In the right-angled triangle ABC, (*plate* II. fig.V. pag.111.) the angle CAB, which opens wider by equal degrees, from the point A towards BC the baſe of the triangle, expreſſes *a motion uniformly accelerated.* The leg AB expreſſes the *time* in which this acceleration happens; and this time is divided into three equal parts or moments, as A 1, 1 2, 2 B. The ſmall lines in the triangle A 1 *k*, repeated at equal intervals, and increaſing in length by equal degrees, denote equal accelerations of the velocity from the inſtant in which a body begins to fall: and the ſmall equal lines in the ſquare 1 *m*, denote an equal velocity during the time expreſſed by the ſide 1 2.

THESE things being firſt conſidered, if we now attend to the *figure*, it will open to us all the conſequences of theſe poſitions.

I.

THE line 1 *k* will expreſs the velocity acquired by a falling body *at the end of the firſt moment of time.* The line 2 *l* will expreſs the velocity acquired at the end of the ſecond moment; and B C the velocity at the end of the third.

II.

IF the body, during the ſecond moment of time, ſhould retain the velocity 1 *k* which it had acquired at the end of the firſt, the ſquare ſurface 1 2 *m k* will be deſcribed; for this ſurface is generated by a continual repetition, or motion, of the line 1 *k* during the time 1 2; as the area of the triangle A 1 *k* is alſo deſcribed by an uniformly-increaſing velocity during the time A 1. But the area of the ſquare is manifeſtly *double* to the area of the triangle. Whence it appears, that a body moving on, during a ſecond moment, with the velocity acquired at the end of the firſt, will fall *twice as far* in the ſecond moment as in the firſt. And the ſame will be true univerſally, that the velocity acquired at the end of any given time, will carry the body twice as far in the ſame time.

III.

But if the velocity continues to increaſe uniformly during the ſecond moment, then the ſpace deſcribed will be as 1 2 *l k*, which is *thrice* as great as the triangle A 1 *k*.

IV.

The *whole ſpace* deſcribed by the body in the two firſt moments, will be as the area A 2 *l*, which is equal to four times the area A 1 *k*; whence it follows, that the ſpace deſcribed by the body in its fall, is as the *ſquare of the time* in which it falls; for here the time is 2, and the ſquare of it is 4.

V.

In the *third moment*, were the body to fall with the velocity 2 *l*, during the time 2 B, the ſpace deſcribed will be as the rectangle under the time and the velocity, that is, as the rectangular ſpace 2 B *n l*, equal to four times A 1 *k*. But as the velocity is ſtill uniformly increaſing, the ſpace will be as the area 2 B C *l*, five times as great as A 1 *k*. And thus will the rectangle under the time and the velocity be always *increaſed by unity*.

VI.

As the triangles A 1 *k*, A 2 *l*, A B C, are all *ſimilar*, or, ſuch as have all their three angles *reſpectively equal* to one another; then as A 2 is the double of A 1, 2 *l* will be the double of 1 *k*; and as A 2 expreſſes the *time*, and 2 *l* the *velocity*, where the time is double, the velocity is double &c. Therefore the *velocity is as the time.*

VII.

If the ſpaces deſcribed in each moment be conſidered *ſeparately*, then the ſpace in the firſt moment will be as 1, in the ſecond as 3, in the third as 5, in the fourth as 7, and ſo on in an arithmetical progreſſion; the common difference being 2.

If we would apply this *theory* to *practice*, it is firſt to be learnt, that in one ſecond of time bodies are found to fall 15 *Paris*-feet and 1 inch, that is 16 feet, and ſomething more, of *Engliſh* meaſure; but we ſhall neglect this ſmall quantity, and ſuppoſe the whole ſpace to be 16 feet in a round number. This hath been diſcovered with ſufficient exactneſs from the *motion of pendulum*'s, between which, and the rectilinear deſcent of heavy bodies, there is ſo cloſe a connection, that neither of theſe can be underſtood independent of the other. It being allowed then, that the ſpace fallen through by a body in the firſt moment of time, is 16 feet; it follows from N°. IV. of the theory, that at the end of the ſecond moment, it will have fallen $16 \times 4 = 64$: at the end of the third moment $16 \times 9 = 144$: at the end of the fourth $16 \times 16 = 256$ &c. All theſe ſpaces being as the *ſquares of the times.*

Hence, if the ſpace be given, through which a body is to fall, we may collect the time wherein it will finiſh its deſcent. For let the number of feet in ſuch a ſpace be divided by 16; then will the ſquare root of the quotient expreſs the time ſought, in *ſeconds* and parts of a ſecond. Thus if the ſpace be 144 feet, 144 ÷ 16 = 9, of which the root is 3. And the converſe of this will be equally true; for if the *time* be given, the ſpace through which the body hath deſcended, may be found from it. If we ſhould deſire to learn the depth of a well, from the ſurface of the earth to the ſurface of the water, let a bullet of lead be dropt into it, and let us ſuppoſe this bullet to ſtrike the water in 5 ſeconds. The ſquare of 5 is 25, which being multiplied into 16 feet, the product will be 400 feet, equal to the depth of the well.

THUS again, were we to ſee a maſs of burning matter, or a large red-hot ſtone, ſhot upwards from the mouth of a volcano, and could obſerve accurately that the whole time of its flight in the air amounted to (as we will ſuppoſe) 30 *ſeconds*; we may thence collect the height to which it aroſe. For a projected body will both riſe and fall in the ſame time; therefore we are to take half the time above-mentioned, or 15 ſeconds: then it will be 15 × 15 × 16 = 3600 feet, or 1200 yards, which is not far ſhort of $\frac{3}{4}$ of a mile.

BUT we are to obſerve, that in the application of this theory, two things are taken for granted, before we arrive at any one of theſe concluſions. Firſt, that the theory itſelf is true in practice to a mathematical exactneſs. That it is very nearly ſo, may be fairly concluded from the experiments which have been made; but nothing more can be concluded with abſolute certainty. Secondly, that the motion is performed without any impediment; in other words, that it is performed in vacuo, or in a medium that gives no reſiſtance; which is falſe in fact: no experiments of any conſiderable compaſs having been made, or being poſſible to be made, without a great degree of interruption from the reſiſtance of air. Upon this account, the well, whereof you are finding the depth, will not be ſo deep as may be imagined by ſeveral feet; nor will the ſtone, projected from the volcano, riſe near ſo high as we have already concluded. This reſiſtance of the air will be different at different ſeaſons: and to find the abſolute quantity of it at any time, and in any particular experiment, is a problem ſo difficult and complicated, as hardly to admit of an adequate ſolution.

In the experiments made by Mr. *Hawkſbee*, of which we have an account in his *phyſico-mechanical experiments* p. 278, and in Sir *Iſaac Newton's principia*, *lib.* 2. *prop.* 40, ſome glaſs balls, filled with quickſilver, were obſerved to fall 220 feet in 4 ſeconds of time. By the theory, they ſhould have fallen 256 feet: therefore, the reſiſtance of the air, added to ſome error in the performance, diminiſhed the ſpace by about $\frac{1}{7}$ of the whole. Some other experiments made by Dr. *Deſaguliers* with balls of lead (ſee *philoſ. tranſact.* N° 362. p. 1071) and executed with a better addreſs than theſe of Mr. *Hawkſbee*, came nearer to the theory. But let us conſider that when theſe balls touched the ground, ſuppoſing them to have deſcended through a ſpace of 256 feet, they moved only at the rate of 128 feet in a ſecond: and what is this to the velocity of light? which according to the uſual computation, moves above a million of times ſwifter than a cannon-bullet. Should this fluid be the natural cauſe of gravity, and ſhould the ſpaces deſcribed be leſs than the theory requires, on account of a nearer approach in the velocity of the body to the velocity of the fluid that moves the body, ſuch a diſcovery is far beyond the reach of all human experiments.

If what hath been here ſaid, ſhould tempt an inquiſitive reader to ſearch farther and deeper into the application of this theory of falling bodies to the motion of pendulums, the flight of bombs and other projectiles; he may find ſatisfaction by peruſing *part* I. c. 6 &c. of Mr. *Rowning*'s ſyſtem of natural philoſophy — S' *Graveſande*'s elements of nat. phil. by *Deſaguliers* b. I. c. 19 & 24 — Mr. *Maclaurin's account of Sir Iſaac Newton's diſcoveries* b. II. c. 5. Or ſee Dr. *Keil*'s introd. to nat. philoſ. *lect.* 15 and 16; than which there is nothing more exact and compleat upon the ſubject.

On Chapter IV.

Page 34. l. 28 &c. In order to prove by ſome eaſy experiment, that the reſiſtance which a body gives to any force that is applied to put it in motion, is *juſt ſo much as ought to proceed from the action of gravity upon it, and no more*; I conſidered, that if the reſiſtance in the ball of a ſimple pendulum ſhould proceed wholly from its gravity; then the ſame force ought to move it more eaſily through a ſegment of a greater circle, than through a ſegment of a leſſer.

Having put together an *extempore apparatus*, I took two balls of lead, the greater of which weighed one pound and an half, the leſſer one quarter of a pound. Theſe were ſuſpended by lines, ſo that the centre of each ball, being at equal heights, was 28 inches below the points of ſuſpenſion. A graduated ſcale being fixed parallel to the plane of their intended motion, I drew the leſſer ball aſide to 24 diviſions from the perpendicular, and having let it fall againſt the

greater,

greater, perceived that the ſtroke of it occaſioned the greater ball to move over 4 diviſions and $\frac{1}{2}$ from the perpendicular. Then I ſuſpended the greater ball from a point 7 feet and 8 inches above its centre; and letting go the leſſer ball from the ſame diſtance as before, found that the application of the ſame force did now occaſion the greater ball to move over 9 diviſions and $\frac{1}{2}$, very nearly. Therefore in this latter trial, where the diſtance of the heavier ball from the point of ſuſpenſion is almoſt *quadruple* of what it was before, the reſiſtance becomes leſſer than before by about *one half*.

THE *times* of the vibrations of different pendulums being in the ſubduplicate ratio of their lengths, their *velocities* compared with each other will be inverſely as the ſquare roots of their lengths; that is, if the length of the greater pendulum be quadruple, and its time of vibration double, its velocity in a ſimilar arch will be $\frac{1}{2}$ the velocity of the leſſer pendulum. In this experiment then, the reſiſtance is leſſened in the ſame proportion with the velocity: but the velocity is deducible only from the active force of gravity; therefore, the reſiſtance muſt be owing to the ſame force. For if the reſiſtance here found be ſuch as ought to flow naturally from the gravity of the body, and no other reſiſtance is to be diſcovered; muſt it not follow, that what has been called a *vis inertiæ* is but the ſame thing with the force of gravity? If not, how are they to be diſtinguiſhed in this experiment?

THAT the reſiſtances above-mentioned do not exactly coincide with the inverſe ratio of the ſquare roots of the lengths, which are 5, 29 and 10, 20, but deviate from it a little, may be imputed to ſome ſmall degree of elaſticity in the leaden balls. However, this error, ſo far as it may concern my argument, is on the right ſide.

From what hath been ſaid there ariſes this corollary — that *the reſiſtance of any ſolid pendulous body may be ſo diminiſhed, as to be leſs than any aſſignable quantity: or, that a body, how large ſoever, may be moved out of its place by a force how ſmall ſoever.* I mention this as a matter of curioſity, though I cannot but regard as trifling all mathematical concluſions which are remote from fact and the common courſe of things.

In defining the *vis inertiæ*, Sir *Iſaac* hath obſerved, that *a body exerts this force, only when it is made to change its ſtate by ſome force impreſſed upon it.* But certainly the force that keeps a body in its ſtate, and the force that reſiſts a change of that ſtate, muſt be the ſame thing: ſo that in our experiment, the ball is either brought down to the loweſt point of the circle, and kept at reſt there, by the *vis inertiæ*, which is falſe; or the force of gravity which brings it to the loweſt point, and would keep it there at reſt, muſt be the force that oppoſes us when we oblige it to change its ſtate. This objection to the *vis inertiæ* is ſo plain and poſitive, and experiment does ſo manifeſtly confirm it, that I confeſs I know not how to get over it, and cannot but wiſh to ſee this principle either wholly diſcarded from natural philoſophy, where it ſeems to have done no good; or better diſtinguiſhed than it hath hitherto been.

As I never think it my intereſt to ſtifle any part of the evidence belonging to a ſubject, I would inform the reader, if he does not know it already, that the *Abbè Nollet* (see vol. I. p. 135 of the *Engliſh* tranſlation of his *lectures*) propoſes an experiment, to prove that the force of inactivity and the force of gravity are not the ſame thing in bodies. There is indeed ſome difficulty in the experiment he ſpeaks of; but it cannot amount to a diſcovery of this *inactive* force, unleſs the body is examined independent of all active forces; which, I think, is not the caſe; and the reader, if he pleaſes, may conſider of it.

ON CHAPTER V.

PAGE 44. l. 21. Some other motions like to that of the two lamps may be contrived in a different manner. Fix a needle upon a pillar of glaſs or ſealing-wax four or five inches in length, and place a ſmall wire upon it, pointed at each end, and bent into the ſhape expreſſed by *fig.* 2. of *plate* I. Let this little machine be ſo placed, that you can electrify the braſs cap in its center by ſparks from a wire hanging perpendicularly over it, but not touching it. If the inſtrument is well made, and the fire ſtrongly communicated, the wire will turn upon its centre as faſt as the flyers of a common jack: and if the room be darkened, you will ſee a ring of light formed by the electric æther as it ſtreams from the points of the wire.

THIS motion is ſo far from being ſtopped or retarded by the reſiſtance of the circumambient medium, that there ſeems to be no better method of accounting for it, than by deriving it immediately from ſuch a reſiſtance. The fire diverging from the points ſtrikes upon the adjacent air; while the air, reacting againſt the ſtreams of fire, or *reſiſting* them, gives a retrograde motion to the points of the wire; juſt as a chair, if placed upon caſters, will run backwards, when the perſon ſitting in it puſhes againſt the wall with a ſtick. If the wall were out of his reach, his ſtretching out the ſtick would make no impreſſion upon the chair: and the ſtreams of fire will be equally inſufficient to produce a motion in this machine, if there be no *air* within the ſphere of their activity. To prove this, I made the three following experiments.

Experiment I.

I ſet the machine upon the plate of my air-pump; and having covered it with a large receiver, electrified it by means of a wire paſſing down to it through a collar of leathers. While the receiver remained full of air, the machine made its revolutions as well within the glaſs as it had done before in the open air.

Exp. II.

THE ſame trial being made when the receiver was exhauſted, no motion enſued. The room being made dark, the operation of the electrical machine was continued: and it was now viſible enough, that the two ſtreams, inſtead of paſſing off from the points in the form of a conical bruſh of rays with its axis parallel to the horizon, went perpendicularly downwards in two parallel lines to the braſs plate of the air-pump: and it was utterly impoſſible that the fire thus perpendicularly directed (had there been no other reaſon for it) ſhould occaſion an horizontal motion in the machine.

Exp. III.

IN order to try whether the fire, moving *horizontally* in the exhauſted receiver, would have any better effect; I placed a ring of braſs wire within the veſſel, and fixed it at ſuch an height, that it coincided with the plane of the intended motion. The machine being again electrified under theſe circumſtances, the fire did now appear to iſſue horizontally from the points toward the braſs ring, and thence it went down to the plate at the bottom, by means of ſome other ſmall wires added for that purpoſe. But notwithſtanding all this, the points of the machine were ſtationary.

Reflexions.

I. The ſtreams of fire do not fall down to the plate by their *gravity*, as two ſtreams of water might be made to do from two orifices in the ends of a ſmall horizontal pipe; for then the velocity with which they iſſue from the points ſhould occaſion them to deſcribe a *parabola*, whereas they deſcribe two ſtrait lines; therefore they are carried down, not by the force of gravity, but by a preſſure of another kind which operates in what we call a vacuum.

2. As the rays of the electric æther do not paſs off from the points in a conical form when the machine is placed in vacuo, but in a perpendicular line; it is certain that the particles of fire do not *recede* from each other ſo much when the air is abſent, as when it is preſent; therefore they do not recede from one another by any inherent *repulſive power*: for were they indued with ſuch a power, they would be more at liberty to exert it when the preſſure of the atmoſphere is taken away, and ought to diverge *moſt* where they are found by experiment to diverge *leaſt*, that is, in an exhauſted receiver.

3. The continuance of motion in any ſpace doth not infer the neceſſity of a vacuum. The contrary to this is ſo true, that a variety of motions may be exhibited, for the producing of which, the preſence of a reſiſting medium is abſolutely requiſite. We have one inſtance of it in this experiment;

periment; and as the analogy I would here point out to the reader is a thing of no ſmall moment, let me deſire him to conſider attentively with himſelf, that if the *glaſs globe* which we here make uſe of as a promptuary or fountain-head of elementary fire, were to ſend forth its ſtore in the ordinary courſe of nature, as the *globe of the ſun* doth ſend forth its light; the motion of this machine would be perpetual, not only in theory, but in practice.

The ſame may be ſaid of the revolution of the two lamps, in the inſtrument deſcribed at *p.* 44: for the motion of thoſe lamps would be perpetual, were their light as perpetual as that of the ſun is.

There is another experiment, which I have frequently performed with much pleaſure, and never without exciting ſome degree of admiration in thoſe who have beheld it. A ſmall light bubble of glaſs being laid on a poliſhed plate of metal, upon which a braſs ring (of about half a foot in diameter) is ſo placed, as to be conveniently electrified without electrifying the plate at the ſame time; the little ſphere of glaſs will deſcribe an orbit about the ring, and will turn at the ſame time about its own axis, the poles of its rotation being nearly at right angles to the plane of its orbit. Here again, if the emiſſion of light from the electrical globe were as conſtant as the ſupplies from the ſun to the planets, the motion of this ſphere would reſemble the motion of the earth as nearly in its perpetuity, as it doth in ſome other reſpects.

In all theſe inſtances, a reſiſting medium does not hinder motion, but actually promotes it, and is one of the immediate cauſes of it: and were theſe little experiments as adequate to the greater phœnomena of the univerſe as they are analogous to them, would render the motion perpetual. An hypothetical train of reaſoning might lead us to conclude, that if leſs matter were in the ſpace, the motion would be more free, and continue much longer: upon the ſuppoſed ſtrength of which concluſion, (if a little geometry were interwoven with it) we might think it neceſſary to get rid of the *air* and of *all ſenſible matter*; and then we ſhould alſo get rid of the cauſes of motion. In a word, the facts now before us ſhew how much we ſhould loſe by the application of this unphiloſophical method; which would promote the ſucceſs of theſe experiments, juſt as much as we ſhould enable a man to run faſter, were we to rid him of the incumbrance of his boots and ſpurs by cutting off his legs.

I think it hardly neceſſary to obſerve, as the thing is ſo obvious, that although the mode of operation in each of theſe experiments is very different, yet the effects in all of them are deducible from the ſame cauſes, fire and air, ordained in a wonderful manner to cooperate with each other.

ON CHAP. VI.

PAGE 49. l. 2 &c. It hath been hinted to me by a learned friend who ſaw this chapter in manuſcript, that the geometrical argument of Dr. *Keil*, though it makes but an indifferent figure in the manner he hath ſtated it, may nevertheleſs be applied to demonſtrate an *interſtitial vacuum* between the parts of bodies. And thus much indeed it may warrant us to affirm, that if the world is filled with an homogeneous matter, all the particles of which are exact ſpheres, of equal ſizes, and all of them in contact; an interſtitial vacuum muſt be the conſequence: and the ratio of the full ſpace to the empty ſpace, will be as the ſolid content of a ſphere, to the difference between that and the content of a cube of the ſame diameter. But then, how many ſuppoſitions is it neceſſary to make, before the way is clear to ſuch a concluſion? and when we have attained it, it leaves my argument but where it found it. For unleſs theſe homogeneous ſpheres are *out of contact*, (the contrary to which is ſuppoſed in the demonſtration) a motion propagated amongſt them will be *mechanical*; and that is all I am contending for. But ſuch mathematical reaſonings are all of them wide of the purpoſe, only tempting us to ramble from the real merits of the cauſe, and to multiply words without knowlege; an obſervation which ought to be as freely applied to what I have hitherto ſaid in anſwer to the demonſtration, as to the demonſtration itſelf. If we leave geometry to take its chance, and make a tranſition to reaſon and obſervation, it will be hard enough to ſhew, that within the whole created ſyſtem of the world there is any ſpace capable of holding a particle of matter, which has not ſuch a particle in it. A ſubtil ſubſtance, (that of fire or light) not to be excluded by the ſurfaces of the moſt ſolid body, is in perpetual agitation, and ready, as experience teaches, to find its way into every channel capable of receiving it. It has likewiſe been proved above, that between the particles of this ſubſtance there is no *repulſive power* to keep them at a diſtance from each other: and as Sir *Iſaac Newton* hath given us ſome fine experiments in his treatiſe of *optics*, whence it is highly probable that even the particles of light are of various ſizes; they will on that account fill up any given ſpace the more compleatly; and the interſtitial vacuities, if they can be called ſuch, will vaniſh into ſomething not worth regarding, becauſe it is impoſſible to be conceived, unleſs the imagination ſhould put a trick upon itſelf; which, I believe, is ſometimes the caſe, when it is contemplating ſuch objects as are beyond its reach. If we keep within the limits of our underſtanding, and attend to nature itſelf as it is diſplayed before our eyes, we may expreſs both ſafely and truly all that is neceſſary to be affirmed upon this occaſion, in the following words, taken from the diſcourſe of *Timæus Locrus* the *Pythagorean* — Πυρ μεν ων δια ταν λεπτομερειαν δια παντων ηκει, αηρ τε δια των αλλων εξω πυρος· υδωρ δε δια τας γας. Απαντα δ᾽ ων πληρη εντι, ουδεν κενεον απολιποντα — "*Fire, by reaſon of its ſubtilty, penetrates into all things; air into all the other elements, except fire; and water into earth: ſo that the world is full of matter, and there is no vacuum left in it.*" N. B. This diſcourſe is ſubjoined to *Plato*'s *Timæus*; or it may be found in *Gale*'s *opuſcula mythologica*.

ON BOOK III. CHAP. II.

An addition to the note *at* page 136.

AS I have here dropped an hint concerning the *danger* which is to be apprehended from *electricity*; it may not be amiſs to give ſome ſhort account of its *good effects*, ſo far as they have fallen under my own obſervation.

A girl of about 12 years of age, the daughter of a ſhepherd in this pariſh of *Wadenho* in *Northamptonſhire*, having frequently expoſed herſelf in the field to bad weather, was afflicted, in the beginning of the ſpring 1761, with flying pains in her limbs, ſoon followed by an *hemiplegia*, or ſtroke of the palſy, which ſeized her ſuddenly as ſhe was at work, and deprived her of the uſe of her limbs on the right ſide, ſo that ſhe was unable to ſtir from her chair, and was carried up and down ſtairs in it, to and from bed, by her father and mother. She complained alſo of a fixed pain toward the bottom of the ſpine, which became ſo violent, that, when in bed, ſhe could reſt in no poſture but only with her face downward.

To remove this ſymptom, a bliſter, to be laid near the part, was recommended by a phyſician, a friend of mine, who happened to viſit me while the girl was in this miſerable condition. It had the deſired effect, and removed this pain in a day or two; but her limbs on the right ſide were ſtill as uſeleſs as before, and ſo invincibly cold, that her mother was employed many times in a day in rubbing them with hot flannels.

The bliſter was continued under the form of a *perpetual bliſter*: but I found, after ſome trial, that no farther benefit was to be expected from it; and having but little hope from the uſe of any internal medicines, I reſolved to electrify her; to which her parents readily conſented, and brought her to me in a chair for this purpoſe. The ſhock was given after the common method; only I endeavoured to adminiſter it in ſuch a manner, that the fire, upon its diſcharge, ſhould follow the courſe of the nerves (from the top of the ſpine downwards) throughout the whole ſide that was affected. After two or three ſtrokes, of which ſhe complained but little though they were very ſevere; I enquired, whether ſhe perceived any warmth or tingling in her limbs? to which ſhe anſwered in the affirmative. When ſhe had received about half a dozen ſtrokes, I diſmiſſed her, ordering her parents to wrap her up warm in bed immediately and bring her to me again in a day or two.

At her next appearance, ſhe was much altered for the better: inſtead of that cold and numbneſs ſhe had before complained of, her limbs had a glowing warmth in them from the time ſhe had left me; and this was followed by a profuſe ſweating, which came on ſoon after ſhe was put to bed, and continued for about two days after the firſt operation. There was likewiſe a copious diſcharge from the bliſter, which for ſome days before had produced no effect, and was in a manner dried up.

After the *ſecond* operation ſhe continued to mend. After the *fourth*, ſhe went by herſelf upon crutches to a neighbour's houſe at ſome little diſtance. At this time, the ſhocks began to hurt her ſo much as to make her ſhed tears; a plain proof, that her limbs had now in a great meaſure recovered their ſenſibility.

After the *ſixth* operation, ſhe was able to walk up a ſteep hill to church, without any aſſiſtance even from a walking ſtick: and during this whole courſe, no medicines of any kind were adminiſtred. Some weakneſs did ſtill remain, which electricity would not remove; therefore I recommended the uſe of the cold bath, by the help of which ſhe ſoon recovered her ſtrength, and is now able to work for a livelihood nearly as well as before, except that her leg on the right ſide is ſomewhat ſhorter than the other, which as ſhe walks does neceſſarily occaſion her to ſink a little on that ſide.

After a time, ſhe was much troubled with an inflammation in her eyes; and there appeared to be ſome violent humours afloat in the habit, owing (as I ſuppoſe) to a tranſlation of the morbid matter from the nerves to the blood-veſſels. I had recourſe to ſome of the methods commonly applied to upon ſuch occaſions: and though the humour in her eyes is not abſolutely cured, it is ſo far corrected as to give but little trouble, and I think ſhe will by degrees entirely get the better of it.

As this caſe ſeems to be a remarkable one, I have given a circumſtantial account of it; and the reader may depend upon the truth of all the particulars, none of which (to the beſt of my knowlege) are in any degree diſguiſed or exaggerated.

I have had other opportunities of trying the power of electricity: and though it ought not to be haſtily cried up as a cure for all diſeaſes, which hath been the misfortune of many an uſeful remedy, ſome there certainly are, to which it may be applied with a proſpect of ſucceſs; and I could be glad to ſee its uſefulneſs properly aſcertained, and diſcreetly limited, by ſome candid and judicious gentleman of the faculty. From what has appeared to me within my own little ſphere, I believe it may be of much ſervice in pains of the *rheumatiſm*, and *paralytic affections*, where they are recent, and the patient not too far advanced in years. Some of the principal diſorders ariſing from *obſtructions* might find great help from it, if they are taken in time: and it might be worth while to try whether it would not ſtop the progreſs of a *gutta ſerena*, or of any other diſorder that may be referred to this claſs, which is a very numerous one. For experience teaches, that it will put the matter of the diſeaſe in motion, and powerfully promote a diaphoreſis: but it may require the ſkill of a regular phyſician, and ſome auxiliaries from medicine, to clear the body properly of the diſeaſe, and bring it to an happy iſſue.

Its greateſt efficacy, I think, will be found in removing (and that in a very ſmall ſpace of time) all ſpaſms or cramps, particularly ſuch as proceed from any ſudden *cold* upon the the external parts. And it ſeems highly probable, that in the moſt extreme caſes of this kind immediate relief might be expected from it, even in that dreadful ſpaſm which affects the muſcles of the back or breaſt, and is ſo common both in the *eaſt* and *weſt-indies*. *Bontius*, in his *Hiſt. Nat. & Med. Ind. Orient.* p. 18. gives this deſcription of it — *Tam repentinus & ſubitus eſt aliquando ejus impetus* &c. *This diſeaſe is ſometimes ſo ſudden and violent, that men are ſeized with it in a moment, and become as rigid as a ſtatue; the muſcles in the anterior or poſterior part of the body being contracted towards their origin; by which means the patient is bent either backward or forward, and fixed in one poſture or the other, as the affected muſcles are ſituated. A ſhocking diſtemper this is indeed! which in the ſpace of four and twenty hours will carry off thoſe who are afflicted with it in extreme agony, while the internal or vital parts are perfectly ſound and in their natural ſtate. The miſery of theſe poor creatures has a ghaſtly effect upon their countenances; eſpecially if the diſorder be attended (as it frequently is) with the* cynic ſpaſm *or* dog-like convulſion, *by which both the cheeks are drawn aſide toward the ears. The face is red, the eyes are livid, the teeth grate together; and inſtead of their natural voice, they utter a ſtrange noiſe, as if they were ſpeaking from a cave under the ground: inſomuch that perſons unacquainted with the caſe would actually take them for dæmoniacs.*

Piso, who has written a natural hiſtory of the *weſt-indies*, tells us the diſeaſe is generally owing to this cauſe — *quod interdiu madidi ac ſudore æſtuantes, ab ingruente nocturno frigore ſibi non cavent* — "that they who have been thrown "into violent ſweats by the heat and labour of the day, "will afterwards too careleſſly expoſe themſelves to the cold "air of the night." He obſerves likewiſe, that on ſome occaſions the teeth are cloſed ſo faſt, that it is neceſſary to break open the mouth with a probe of iron; and when this is done, the patient is perhaps utterly incapable of ſwallowing; ſo that nothing can be adminiſtered by the mouth to give him any help.

That an electrical operation might remove the cauſe even of this diſtemper, how frightful ſoever its ſymptoms may be, I was induced to believe, firſt, by the following accident. A few months ago, one of my maid-ſervants, by taking ſome cold in the night, aroſe in the morning with that ſpaſm which is commonly called a *crick* in the neck; ſo violent, that her head was drawn aſide toward one ſhoulder, and could not be ſtirred any way without cauſing an acute pain. I ordered her to place herſelf upon a ſtand ſupported by feet of glaſs, with a deſign to electrify her; and deſired a perſon preſent to draw ſparks with a finger from the point where the greateſt pain was felt when ſhe attempted to move her head. By this means, in a minute or two, her head came nearer to the perpendicular, and by continuing the operation, was very ſoon reſtored to its natural poſition. Some ſoreneſs remained in the part; but that was eaſily removed by keeping her neck warm. All the ſparks that were drawn upon this occaſion raiſed ſo many little red puſtules or bliſters; which I think is not uſual if the part be in an healthy ſtate.

This complaint, though leſs in degree, is the ſame *in ſpecie* with that above-mentioned; and is ſometimes of bad conſequence, as it hath been known to be fixed upon a perſon for ſeveral years by being improperly treated at firſt. Now if electricity can give ſuch immediate relief in one of theſe caſes, much might be expected from it in the other. And the probability of this will farther appear, if we conſider the ordinary methods of cure, which are the ſame in intention with thoſe preſcribed by *Hippocrates*, and theſe are, bleeding, friction, ſudorifics (if they can be adminiſtered) and anointing the patient externally with the eſſential aromatic oils, as of cloves, mace, oil of turpentine &c. for theſe oils are but ſo many vehicles of elementary fire. And would not the agent itſelf, unincumbred with the vehicle, and paſſing inſtantaneouſly through all the moſt minute ducts of the part affected, produce the deſired effect with much greater ſpeed and efficacy, with leſs trouble, and equal ſafety?

The force of the electrical fire is principally exerted upon the *nerves* and *tendons* of the body: whence there is reaſon enough to believe, that this fluid is the ſame with that *ſomething* which learned phyſicians have ſo much diſcourſed upon under the name of *animal ſpirits*. The nerves do not appear as if they were deſigned to admit within them any animal-fluid or liquor, unleſs it be an indolent lymph which is neceſſary to keep them moiſt: but their pellucidity indicates that they are properly adapted to give a direct paſſage to the fluid of *light*; for they are tranſparent, and that not tranſverſely, but longitudinally, or in the direction of their fibres. I once obſerved this accidentally, as ſome eyes of ſheep and oxen, which I had procured in order to diſſect them, were lying before me upon my table. One of theſe eyes *ſhone* in the day-time, much in the ſame manner as the eyes of ſome animals do in the dark. Not being able to account for this, I endeavoured to examine the fact as narrowly as I could; and at length perceived, that if my hand were interpoſed between the neareſt window and the extremity of the optic nerve (a part of which, nearly an inch in length, remained with the eye, and was accidentally pointed toward the window) the light immediately diſappeared.

THIS led me to conſider, whether the light that appears in the eyes of ſome animals in the night time, is really a *reflexion* of light from the eye, as is commonly ſuppoſed; or whether it does not rather paſs into the eye, through the optic nerve, from the body of the animal? Dr. *Willis* calls it *jubar inſitum*; and, for my own part, I cannot conceive how this ſhining can be occaſioned by a reflexion of light from the *choroides* in the bottom of the eye, when the light to be reflected (as in a dark night) is not viſible before its entrance into the eye.

IF a candle be held before the eyes of a dog, and you place yourſelf in the line of reflexion, the light will be viſibly reflected from his eyes, becauſe the illumination is ſufficiently ſtrong: but when there is no viſible illumination at all, how ſhould it account for the like effect? whence it is more reaſonable that this appearance ſhould be owing to a light from within the body of the animal, which being weaker than the light of the day, but ſtronger than the light of the night, is viſible in the night and not in the day. The light of thoſe other bodies which ſhine in the dark, is inherent in the bodies themſelves; as in putrifying veal, fiſh, rotten wood, phoſphorus, the glow-worm &c. concerning the laſt of which, that eminent anatomiſt and philoſopher *T. Bartholine* hath this obſervation — *Habent illæ (cicindelæ)*

ſi examinentur, lucidum humorem in poſteriore parte corpuſculi, ubi cor latet, quo movetur cor & illuminatur, tamdiu ſplendore ſuo relucentem, quamdiu cor vivit & movetur. Si tam patulum oculis noſtris eſſet pectus animalium, quam cicindelæ tranſparens corpuſculum, forſan non abſimile lumen in corde appareret, quod extinguitur quamprimum externo aeri patet. &c. "*If a glow-worm be examined, it will appear to have a lucid liquor in the hinder part of its body where the heart is placed, by which the heart is moved and illuminated; and this fluid retains its light, ſo long as the heart of the inſect retains its life and motion. Were the breaſts of animals as pervious to the ſight as the tranſparent body of the glow-worm, perhaps a light, analogous to this, might appear about the region of the heart, which light is extinguiſhed the moment it is expoſed to the open air.*" T. Barthol. Epiſt. de flammulâ cordis. p. 4.

ON CHAP. III.

An addition to the note *at page* 153 — 154.

SPEAKING of the *force* that is exerted in the experiments on *artificial freezing*, I have called it a force which *art would find it difficult to meaſure*. Such I then imagined it to be, and contented myſelf with relating an

experiment, from which it could only be gueſſed at in the groſſeſt manner. But being deſirous of obtaining ſome certainty in an affair which deſerves a deeper examination, I contrived a way, this laſt winter, of meaſuring this force to a ſufficient degree of exactneſs.

I made uſe of the *box* already deſcribed in the foregoing part of this note. It was filled as before with water purged of its *air*; and being covered, but not ſcrewed down, it was placed upon an oaken pedeſtal, which had for its baſe a flat hewn ſtone of about a foot ſquare. The ſhorter arm of a very ſtrong lever was made to preſs upon the top of it; and this lever was compounded with two others, by which the power of it was greatly increaſed. At the extremity of the longer arm of the moſt remote lever, a cord was faſtened, which ran over a pulley, and had a weight of 28 lb. hanging at the end of it. This weight, acting as a *mechanical power*, made the ſhorter arm of the firſt-mentioned lever preſs down the cover of the box with a certain force, which, according to the general law of all mechanics, was to the 28 lb. at the end of the line, *as the ſpace moved through by the power, to the ſpace moved through in the ſame time by the weight*: but theſe ſpaces being compared with each other, I found that the greater was to the leſſer as 82 to 1. So that if we multiply 28 by 82 the product will be 2296 lb. to which ſomething muſt be added for the friction of the machine, though I took what care I could to render its motion as true and eaſy as poſſible. While the cover of the box was preſſed down by ſo great a weight, the water incloſed within it was made to freeze; and the agent by which the water was congealed did fairly overcome the whole force of the machine.

Though this experiment ſucceeded ſo far as to give me the ſatisfaction I wanted, it was interrupted by an accident I did not look for. When the water began to freeze, and the cover of the box to be raiſed up from the rim, I perceived that the ground yielded under the preſſure, and that the flat ſtone which ſerved as a baſis to the pedeſtal was ſunk a little below its firſt poſition. By this means the force was at firſt ſpent upon the ground, and did not take place in the machine, till the ground would no longer give way. It was, however, ſo ſenſibly perceived in the machine likewiſe, as to prove that this force was at leaſt ſuperior to *one ton, two hundred and ninety ſix pounds*. How much greater it may prove to be, I cannot as yet affirm; though I believe my apparatus would anſwer the purpoſe if it were required to purſue the experiment to the bottom. But there are ſo many circumſtances to be nicely attended to in order to make it ſucceed, and ſo much time and trouble to be beſtowed upon it out of doors in cold weather, that my patience was wearied out, for this winter at leaſt, by a ſingle attempt.

The cavity of the box, as I find by gauging it, contains 5 cubic inches and $\frac{6}{10}$. Water when it freezes commonly increaſes in its bulk by $\frac{1}{9}$ of the whole: therefore the ſpace occupied by the æther which exerted all this force upon the machine, was equal only to about $\frac{6}{10}$ of a cubic inch. And hence it will appear by a calculation, not worth particularizing, that the force of this æther (even in this experiment, which undoubtedly falls very far ſhort of the whole truth) was about *two hundred and ſeventy three times greater than the ordinary preſſure of the atmoſphere.*

Mr. *B. Robins*, the engineer, found by ſeveral accurate experiments, that the force of fired gunpowder is about 1000 times greater than the preſſure of the atmoſphere: and the force of that agent which conſolidates water into ice, may be found equal to it, for ought that has yet appeared to the contrary. We do not wonder at the power of fire, when it acts with a vehement degree of *heat*, altho' its effects are ſo great that nothing can withſtand it, as in gunpowder, and in the engine for draining mines by the ſteam of boiling water. But here we have the ſame ſubſtance (for the water was perfectly cleared of its *air)* exerting a moſt aſtoniſhing force, even when reduced to the temperature of *ice*; and we may judge from the phœnomena of *cohering bodies*, that this force will be greateſt when the cold is greateſt.

The expanſion occaſioned by heat, and this expanſion of water by froſt, are certainly not to be accounted for in the ſame manner. My own opinion, which I readily ſubmit to the judgment of others, is this — that the force of *heat* ariſes from a vehement *motion* and vibration of the particles of fire; whereas this *cold force*, like the ſhock in electricity, doth not proceed from elementary fire as it gives heat, but as it *reſtores an equilibrium* which by ſome means hath been interrupted.

This diſtinction I would ſupport, by giving an inſtance of ſomething ſimilar to it in the element of air, which acts in two ſeveral capacities, *viz.* as *wind*, and as *ſound*, correſponding reſpectively with thoſe two different operations of fire. *Sound* ariſes from a *vibration* or *undulatory motion* of the parts of air; whereas *wind* ruſhes into a more rarefied ſpace to *reſtore an equilibrium.* And what is very wonderful, and very true, though it be hard enough to conceive, theſe two operations will either meet or croſs without diſturbing one another. If a great gun be fired two or three miles off to the *eaſtward*, and the wind blows hard at the ſame time from the *weſtward*, the ſound will arrive in the ſame ſpace of time as if its motion had concurred with the motion of the wind. In ſome degree, the ſame thing is obſervable even in ſuch a fluid as water; one ſtream of which, if it moves ſwiftly over a ſmooth bottom, will croſs many others nearly at the ſame angle, and appear to have ſuffered little or nothing from them, as I have frequently obſerved with ſome ſurprize.

THESE conſiderations will enable us to ſee in a proper light the following experiment, to which I have alluded at *p*. 134. *l*. 19. though I did not think it neceſſary to mention it in that place.

IF an iron bar of ſome length be heated red hot in the middle, and you electrify it at one end, a ſpark of the electric æther may be drawn from the other. Such philoſophers as do not carefully diſtinguiſh between the motions of fluids and thoſe of ſolid maſſes, will aſk us how this can be, if fire and the electric æther are ſuppoſed to be the ſame thing? Here is elementary fire going off in a ſtream at right angles to the axis of the bar; while the electric æther can go ſtrait from one end to the other, without being abſorbed, diſſipated, and carried off in the common ſtream at the place which is red hot, or without being *obſtructed in its paſſage by a fluid of the ſame kind, as there is reaſon to believe it would be*. But indeed there is not the leaſt reaſon to believe this, as the parallel now before us will plainly demonſtrate. For when a cannon is fired off, the air is thrown into ſubtil waves, ſpreading themſelves very ſwiftly throughout a circular ſpace, of which the ſonorous body is the centre. But a ſtrong wind will blow acroſs this ſpace, even through the centre of it, without being ſtopped itſelf, and without retarding the motion of the ſound. How unphiloſophical would it be to argue from this obſervation, that the element which brings ſound to the ear, and the air which blows acroſs it as a wind, are two different fluids? Who will venture to ſay, that the current of wind or the waves of ſound ought to be *obſtructed by a fluid of the ſame kind*, ſeeing all this is falſe by experience? And if in the *air* two ſuch effects can be produced without any conſiderable diſturbance, and may conſiſt well with each other though they are apparently oppoſite and inconſiſtent; how much more will they conſiſt in the element of *fire*, the ſubtilty of which will admit of a greater variety of motions, all of them more perfect in their kind, as fire is more ſubtil than air.

This experiment may alſo be rightly underſtood only by conſidering what effect the *preſſure of the air* will have on the ſurface of the iron bar. For if the part that is red-hot could by any contrivance be included in a ſpace exhauſted of air, the fire would be diſſipated, and the bar would grow cold much ſooner there than in the open air. Now the ſame preſſure which will ſuffer the fire to eſcape but ſlowly, and in a certain ſurpluſage, under the form of *heat*, doth alſo ſuppreſs and keep in the *electrical current*, ſo that it ſhall go freely from one end of the bar to the other without being diſſipated; whereas this, together with the heat, would be diſſipated *in an exhauſted ſpace as faſt as it could be infuſed.*

ON BOOK IV. CHAP. I.

PAGE 188. *l.* 6. &c. Men of learning have been divided in their ſentiments concerning the optical knowlege of the ancients. Some are ſo ſwallowed up by an admiration of the diſcoveries that have been made in the laſt and in the preſent century, that they are tempted to paſs ſentence upon the ſkill of the ancients, before they know what the ancients have ſaid for themſelves; and they imagine there is abſolutely nothing to be ſaid on the oppoſite ſide of the queſtion but what ariſes from an irrational attachment to the wiſdom of antiquity. But, ſetting apart all prejudice to one ſide or the other, I ſhall humbly offer a few ſhort hints, only as an encouragement to ſome farther examination of the ſubject, by thoſe who have learning and leiſure enough to undertake it.

THAT the ancients were acquainted with the *burning* power of *mirrors* and *glaſſes* is not diſputed. M. *Buffon* of *Paris* contrived a method ſome few years ago of ſetting deal boards on fire by the reflected rays of the ſun, at the diſtance of 200 feet, merely by a proper application of a number of plane looking-glaſſes: an experiment which did in a great meaſure re-eſtabliſh the credit of what has been reported of *Archimedes* burning the ſhips of the *Romans* at a conſiderable diſtance from the walls of *Syracuſe*. See *Phil. Tranſact.* N°. 483. But although burning-glaſſes were known to the ancients, the moderns have denied that they did ever obſerve the power of glaſs in *magnifying* objects, affirming that not the leaſt hint of ſuch a thing is to be found in any of their writings. How they could be poſſeſſed of the art of glaſs, and make a daily uſe of glaſs veſſels of all ſorts, without obſerving that objects appear larger through glaſs that hath a ſpherical ſurface, would to me, I confeſs, be hard enough to conceive, though there were not a ſingle paſſage of antiquity that made any mention of it. But that the ancients did actually obſerve this, is clear from their own accounts. *Seneca* has theſe words — *Poma per vitrum aſpicientibus multo majora ſunt* — or, as he expreſſes it in another part of the ſame book — *ſi innatant vitro* — "apples "appear *greatly magnified* to thoſe who view them as they "ſwim in a veſſel of *glaſs*." *Nat. Quæſt. lib.* I. *cap.* 6. This obſervation, it may be ſaid, if they went no farther, could not be applied to any uſe; the advantage that might be obtained by immerging the leaf of a book into a veſſel of water, in order to ſee the letters ſomewhat magnified, would never be worth the trouble. To read ſmall letters with any tolerable convenience, either a portion of a ſphere of ſolid glaſs, or an hollow ſphere of glaſs filled with water, muſt be placed between the object and the eye of the ſpectator. The latter of theſe they certainly had in uſe, and applied them as *dioptric* burning-glaſſes. That they could do this, and be ignorant of their magnifying power, would not be credible; and the contrary is plainly affirmed. *Seneca* obſerves — *Literæ quamvis minutæ & obſcuræ, per vitream pilam aquâ plenam, majores clarioreſque cernuntur.* "Let"ters, though minute and obſcure, appear larger and clearer "through a glaſs bubble filled with water." *Ibid. cap.* 7. It is ſcarce probable that any curious mathematician, of whom there were many among the ancients, ſhould have been familiar with ſo important an experiment without going farther: but how could this be done, unleſs they underſtood the way of *grinding* glaſs, ſo as to form it into

portions

portions of larger ſpheres? *To do this* (ſays Dr. *Hook) they muſt have known how to have wrought and ground their glaſſes as we do; whereas in all probability the ancients knew only how to blow their glaſſes and make veſſels of it.* See Dr. *Smith*'s Optics. Vol. II. p. 16. Art. 94 of the *Remarks.* But here Dr. *Hook* was under a miſtake; for the ancients gave a figure to their glaſs, not by blowing only, as he has imagined, but by the three different methods in uſe with the moderns. *Pliny* deſcribes the practice of the ancient artiſts in theſe words — *Aliud flatu figuratur, aliud TORNO TERITUR, aliud argenti modo cœlatur, Sidone quondam iis officinis nobili, ſiquidem etiam ſpecula excogitaverat. Hæc fuit ANTIQUA RATIO VITRI.* "Some glaſs is faſhioned by blowing; ſome is ground upon a wheel, or in "a turning-lath; and ſome is engraved like ſilver. *Sidon* "was celebrated for its glaſs-works, having alſo invented "*ſpecula.* Such was the ancient art of glaſs." *Nat. Hiſt. lib.* 36. *cap.* 26. In another place *Pliny* calls this city of the *Phœnicians* — *Sidon artifex vitri. Lib.* 5. *cap.* 20. As to the words — *ſiquidem etiam ſpecula excogitaverat* — I quote them as they ſtand in the text of the *variorum* edition; but the ſenſe of the author is not clear. He may poſſibly mean more than we ſhould expect: *ſpecula* is a proper word to ſignify *teleſcopes*; and *excogitaverat* muſt allude to ſome notable *invention.* But as we may ſift out of a dark expreſſion more than the author himſelf underſtood by it, I dare not lay any great ſtreſs upon it.

That glaſs was *ground* by the ancients, may be proved from the writings of *Seneca*; for how could a *priſm* of glaſs be made by *blowing?* Yet ſuch things were in uſe among the *virtuoſi* of *Rome* in the days of *Nero* — *Virgula ſolet fieri vitreæ — pluribus angulis — hæc ſi ex tranſverſo ſolem accipit,*

accipit, *colorem talem*, *qualis in* arcu *videri ſolet*, *reddit.* "A rod or bar of glaſs (ſaith *Seneca)* is made, with ſeveral "angles, which, if it receives the rays of the ſun through "it, makes ſuch colours as we ſee in the *Rainbow.*" *Nat. Quæſt. lib.* 1. *cap.* 7. And he ſpeaks of *multiplying* glaſſes, the ſeveral faces of which muſt undoubtedly have been cut upon a wheel. *Si aptè fabricata foret*, *totidem redderet ſoles*, *quot habuiſſet inſecturas. Ibid.* But there is one obſervation I ought not to omit, *viz.* that although *Seneca* ſpeaks ſo expreſſly of the uſe of glaſſes, and mentions the *refraction of an oar in the water*, he does not ſeem to have any idea of the *principles* upon which theſe effects are brought to paſs.

Spectacles are ſuppoſed to have been firſt known about the latter end of the 13th century: but there is little doubt to be made that our famous countryman Friar *Bacon* was acquainted both with ſpectacles and teleſcopes before that time. Upon any other ſuppoſition, his own expreſſions on the ſubject are altogether unaccountable. And I am inclined to believe, that ſome traces may be found of an earlier date. Amongſt the *adages* of *Junius* (publiſhed in the ſame volume with thoſe of *Eraſmus)* this ſhort paſſage is extracted from *Piſidas*, a *chriſtian* writer who flouriſhed at *Conſtantinople* in the 7th century — Τα μελλοντα ως δια διοπτρȣ συ βλεπεις "you ſee things future as by a *dioptrum.*" What can this *dioptrum* be? Muſt we not underſtand by it either a *ſpectacle-glaſs* or a *proſpective-glaſs?* We know of no other inſtruments whereby things indiſtinct and at a diſtance may be ſeen as if they were near at hand. The art by which this is brought to paſs is plainly the ſubject matter of the ſimile. The author *(Junius)* in whom I accidentally met with this paſſage, being himſelf ignorant of the teleſcope, takes this dioptrum for the *ſights* of a quadrant, or ſome other geometrical inſtrument. But how can theſe ſights (unleſs they are *teleſcopic* ones) afford any reſemblance to that prophetical ſagacity in the mind, whereby it ſees things as yet at a diſtance; to which nothing in the world can be ſo nearly like, as that power of ſeeing diſtant objects by the help of optical glaſſes. As to the *plain ſights* of a quadrant &c. the eye is ſo far from being aſſiſted by them when it views a diſtant object, that the chief difficulty an artiſt has to contend with, is that of making the accuracy of the line of collimation upon the inſtrument conſiſt with clear and diſtinct viſion.

It may ſeem ſtrange indeed, that if *dioptric glaſſes* were anciently in uſe, we ſhould hear of them no oftener in the writings of the ancients. This may be hard to account for; and yet it may be very unſafe to draw a poſitive concluſion from negative evidence. Friar *Bacon* mentions the refractions of the ſun's rays through a glaſs ſphere: but as he does not ſay *totidem verbis* that he ever viewed an object through ſuch a ſphere, the learned Dr. *Smith* is of opinion (if I do not miſunderſtand him) that he had no experience of its *magnifying* power. See *Opticks*. Vol. II. p. 21. R. And had *Seneca* deſcribed his glaſs ball filled with water only as a burning glaſs, this might have tempted us to argue, that he knew nothing of its uſe in *magnifying letters:* only he happens to have precluded ſuch a conjecture by declaring the contrary. He might know more than he has ſpoken of: the mathematicians and workers in glaſs of thoſe days might know more than he did: and the ancient *Greeks* and *Phœnicians* might know more than the *Latins:* but the accounts we have of many ancient works of art are ſo much broken by the injuries of time, the ambiguities of language, the ſucceeding intereſts of different ſects of philoſophers, and the barbariſm of the intermediate ages, that it muſt now be very difficult to eſtabliſh this ſuppoſition by ſo many and clear proofs as ought to be deemed ſatisfactory.

If we ſhould argue *by inference*, the caſe will be a little altered. The cabinets of the curious are ſaid to contain ſome very ancient gems of admirable workmanſhip, the figures upon which are ſo ſmall, that they appear beautiful through a magnifying glaſs, but altogether indiſtinct and confuſed to the naked eye. And if they cannot be viewed, how could they be wrought without the aſſiſtance of glaſſes? How could it be known, that the moon has a form like to that of the earth; that it has plains, hills and vallies in it? When it is ſeen through a teleſcope, the diſpoſition of the lights and ſhadows render this very evident upon the common rules of perſpective; but no ſuch thing appears to the naked eye. How could it be known, that the *via lactea* ariſes from the combined rays of an infinite number of ſmall ſtars? How came the true ſolar ſyſtem to have been ſo well known and deſcribed by the moſt eminent philoſophers of antiquity; when the beſt, and indeed the only deciſive proofs of it muſt be derived from the teleſcope? But above all, how came it to be aſſerted (as we have already ſeen at p. 192) that *the ſphere of the fixed ſtars is ſo immenſe, that the circle of the earth's annual orb bears no greater a proportion to it than the centre of any ſphere bears to its whole ſurface?* This does ſo far exceed the comprehenſion of the human mind, that it is now the moſt indigeſtible truth in the modern aſtronomy; and never was aſſerted ſince the revival of the *Pythagorean* ſcheme, till Dr. *Bradley*, by a courſe of the moſt accurate obſervations that ever were made with a *teleſcopic apparatus*, reduced the *annual parallax* of the fixt ſtars to an inſenſible quantity.

MANY ingenious men, and ſome good mathematicians who never deſcended to the practical part of aſtronomy, are ready to ſuſpect the truth of all ſuch concluſions in the ſcience as depend upon the meaſuring of angles to a very few *ſecond* minutes of a degree. But for my own part, though I would not be bound to follow the *ſpeculations* of every modern aſtronomer, I am not diſpoſed to queſtion the truth of any aſtronomical diſcoveries pretended to by ſo great a maſter of the ſcience as Dr. *Bradley*, furniſhed as he is too with the fineſt inſtruments in the world: and I think I can gueſs very nearly at the degree of exactneſs that may be attained, by what I have been able to learn in this way from my own experience. I beſtowed ſome pains in contriving and executing an inſtrument of a large radius, with teleſcopic ſights &c. which in the many obſervations I have made with it, has far exceeded my firſt expectations. In *June* 1761 I had an opportunity (which I had long deſired) of obſerving the *obliquity of the ecliptic*; and knew I could ſo far depend upon the obſervation, when compared with that of Mr. *Flamſteed* and ſome others, as to be morally certain that this obliquity is not ſo great at preſent, by about *one minute* of a degree, as it was an hundred years ago. I tranſmitted the reſult of my obſervation to a learned gentleman, eminently ſkilled in aſtronomical ſtudies, who has very lately informed me, that it differs only 2'' from the obliquity at that time as determined by Dr. *Bradley*.

These few reflexions on the optical knowlege of the ancients I have thrown haſtily together, merely as an eſſay, to be carried farther (if it is worth it) by thoſe who are more advantageouſly ſituated for ſuch an employment. My reading is ſo circumſcribed by the books in my own ſtudy, that I have no opportunity of going any deeper into this affair at preſent: nor have I any intereſt on one ſide of the queſtion or the other. As the ancients were in poſſeſſion of much valuable truth, and have delivered down to us the beſt elements, and ſome of the higheſt concluſions, in almoſt every ſcience; it is a piece of juſtice due to them from all men of letters, never to pronounce upon them from their own prejudices; but to obtain what light they can by a peruſal of their writings: an employment which will be attended with more pleaſure and ſatisfaction, and turn alſo to a much better account, than the taking up of an opinion upon truſt from any modern writer whatſoever.

FINIS.